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#1637
rev. Apr. 1939

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SUGAR-BEET CULTURE in the HUMID AREA of the UNITED STATES

FARMERS' BULLETIN Nº 1637
U. S. DEPARTMENT of AGRICULTURE

THIS BULLETIN outlines the practices found to be successful in sugar-beet growing in those areas of the United States where their growth is dependent upon natural rainfall without recourse to irrigation.

The beet-sugar industry has developed in those districts where soil and climatic conditions are especially favorable. An adequate supply of moisture, especially during the growing season, soil of a proper type, and a long, moderately cool growing season are essential. The adaptability of the sugar beet has permitted its culture on a wide range of soils, but the more satisfactory yields are generally secured on the heavier types. The soil should have good depth, fairly high organic content, adequate drainage, high moisture-holding capacity, and a favorable soil reaction. When properly grown, the sugar beet fits well into a rotation, furnishes a high return, and is valuable for the proper maintenance of soil fertility and tilth.

In the culture of sugar beets intensive measures are necessary. Careful preparation of the soil for the seedbed, proper planting practices, abundant use of manure and fertilizers, and proper cultivations are essential in securing satisfactory returns.

Weed control is extremely important, especially in the early half of the season when the beet plants are small and may be injured by their rapidly growing weed competitors.

The sugar beet furnishes, in the form of beet tops, beet pulp, and molasses, valuable feeding materials for use on the farm, and these may properly be considered as additional returns from the beet crop.

This bulletin supersedes Farmers' Bulletin No. 568, Sugar-Beet Growing Under Humid Conditions.

Washington, D. C.

Issued November 1930
Revised April 1939

SUGAR-BEET CULTURE IN THE HUMID AREA OF THE UNITED STATES [1]

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INTRODUCTION

SUCROSE, the sugar of commerce and kitchen, is extracted from the tissues of the sugar beet and the sugarcane. Whichever plant it comes from, the product, when pure, is identical in all properties and for all purposes.

The sugar beet is cultivated for the sugar that the plant stores in its roots. In comparison with other plants, the quantity stored is high, amounting, on the average, to 15 percent of the total root weight. This sugar is formed in the leaves from water and carbon dioxide by chlorophyll (the green coloring matter of plants), sunlight supplying the energy for this chemical process. In the period of rapid growth, much of the sugar made is consumed by the plant, but, as growth is retarded in late season, sugar storage increases. The value of the crop depends primarily on the acre-yield of roots and the richness of the roots in sugar. This bulletin stresses methods for producing high tonnages of roots of high quality. The sugar beet also produces valuable byproducts such as beet tops, beet pulp, and molasses, which add to the returns from the crop. Methods of utilizing these byproducts are given.

Although the sugar beet is now grown in a wide territory under a considerable range of climatic and soil conditions, it cannot be grown successfully in all parts of the United States. In comparison with other field crops, it is an expensive crop to grow and requires much

[1] The investigations upon which this publication is based were conducted in cooperation with the Michigan and Ohio Agricultural Experiment Stations. Acknowledgment is made to the Farmers and Manufacturers Beet Sugar Association for permission to use the following: Title-page illustration, figs. 4 to 26, inclusive, 32, and 33; and to the Farm Crops Department, Michigan State College, for figs. 27 and 28.

hand labor. In order to compete successfully with other crops, a high yield of roots per acre must be secured, and these must be of sufficiently high sugar content to permit profitable extraction of sugar. The commercial crop is harvested at or near the end of the period of vegetative growth,[2] and the roots must have reached a relatively large size and high quality. In the establishment of factories, the beet-sugar industry has sought to find those districts in which climatic and soil factors bring about such a development of the plant as to make the crop profitable both to the farmer and the processor.

SUGAR-BEET AREA IN THE UNITED STATES

From the standpoint of sugar-beet production, the United States may be divided into three fairly distinct areas by differences in climate or cultural conditions. These are: (1) The humid area, located in the North Central States; (2) the Mountain States area; and (3) the Pacific coast area. Of the total acreage of sugar beets produced in the United States, about 25 percent is in the humid area, about 55 percent in the Mountain States area, and about 20 percent in the Pacific coast area. In 1938 the total acreage of this crop harvested was approximately 931,000 acres.

In the humid area, beet-growing districts have been developed in Michigan, Ohio, Indiana, Wisconsin, Minnesota, Iowa, Illinois, North Dakota, and eastern Nebraska. The production of the crop is not general over this whole area, but is restricted to districts where the soil and other conditions have favored the crop.

CLIMATIC ADAPTATION

For successful production, the sugar-beet crop requires much moisture during the growing season. The quantity of water required for continuous growth bears a very definite relationship to the amount of foliage present, more and more being needed as the foliage increases and the season becomes warmer. (Conversely, more foliage will be developed where there is an ample supply of moisture.) In the humid area, nearly half of the total annual precipitation normally comes during the months of the growing season, May to September, inclusive, and, while the precipitation during the early part of the growing season is probably more than actually required by the growing crop, the quantity normally received during August and September is not likely to exceed what the crop can use. During the latter part of the growing season, after the crop has drawn heavily upon the moisture reserve in the soil and the precipitation received is not sufficient to meet the demands of the foliage, there is usually a decrease in the amount of foliage present. However, great seasonal variations occur in all the humid sugar-beet-growing districts. During October and November, the harvesting period in the humid area, the precipitation is usually much less than during the growing period.

Experience has shown that, in addition to an adequate supply of moisture, the sugar-beet crop is favored by a long and moderately

[2] Selection has caused the sugar-beet plant to assume the biennial habit. That is, when it is permitted to complete its life cycle it makes its vegetative growth and stores sugar during the first season, remains dormant over winter, and then resumes growth and produces seed the second season. The roots may increase somewhat in size during the second season, or the period of seed production, but they generally become very fibrous or woody, and the sucrose content is generally reduced to such a point as to render them unfit for extraction purposes.

cool growing season. Nearly all the beet-sugar factories operating in the North Central States are located between the isotherms of 67° and 72° F. mean summer temperature (May to September, inclusive), as shown by figure 1. While it is possible to grow the sugar beet under other temperature and climatic conditions than those indicated, attempts at its culture outside of this zone have not proved promising. Within the geographic borders of the isotherms, its culture is further limited by the extent of suitable soil types and other factors.

In the localities of the humid area where the sugar-beet crop appears to be permanently established, there is reasonable certainty of warm

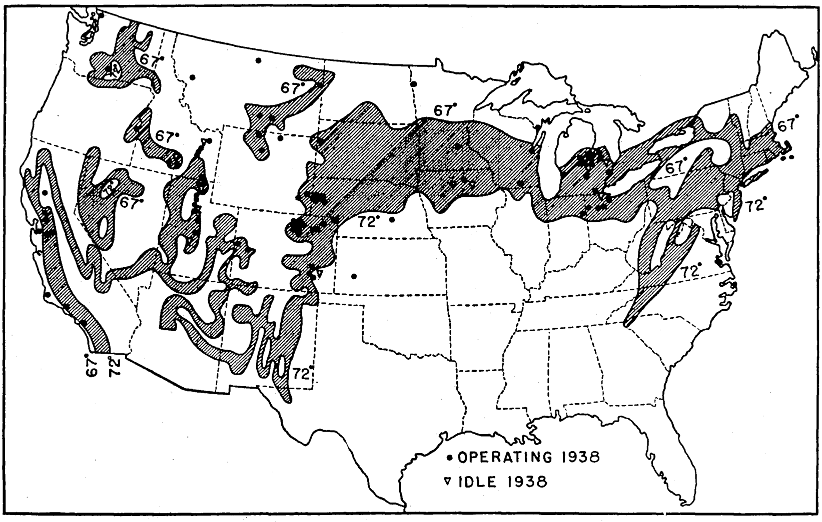

FIGURE 1.—Location of beet-sugar factories in the United States. The zone lying between the mean summer isotherms of 67° and 72° F. is shown as a shaded portion.

days and fairly cool nights during the growing season. These combine to favor the rapid growth of the crop. Since the sugar-beet root is a vegetative structure, growth will continue as long as temperature and moisture conditions are favorable, and the longer this period the higher will be the tonnage. However, the value of the crop depends largely on the sucrose content, the storage of which is unfavorably influenced by undue vegetative growth. Although warm and sunny days prevail in the latter part of the season, progressively cooler nights slow up vegetative growth and correspondingly accelerate sucrose storage.

In general, then, the climatic conditions that favor the production of sugar beets in the humid area are found where the rainfall is distributed throughout the growing season, with summer temperatures favorable to continued and rapid growth, and where the fall months are sufficiently dry to check the vegetative growth to some extent but not sufficiently dry to stop it altogether and the temperatures also aid in checking the vegetative growth and promoting the storing of sucrose.

SOIL REQUIREMENTS

Proper soil conditions must be provided in order to produce a satisfactory crop of sugar beets. Experience has shown that the mineral-soil types that combine the necessary characteristics to make them adaptable for sugar-beet production are usually the dark-colored, heavier types, such as loams, silt loams, clay loams, and clays, and it is upon these types of soil that the greater acreage is grown, although satisfactory yields have often been obtained upon sandy loams and, in some instances, upon the still lighter textured sandy soils. With the organic soils, or mucks, the yield depends very largely upon the characteristics of the muck; many of these soils are found to be entirely

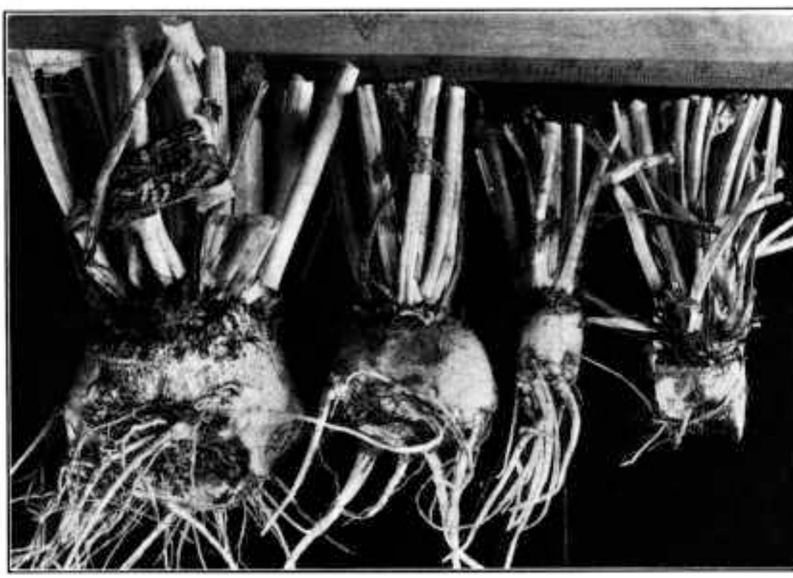

FIGURE 2.—Sugar beets of undesirable shape.

unsuited to the growing of sugar beets, while others, although giving satisfactory yields, produce beets of low sucrose content.

Since the darker colored, heavier types of mineral soils have been found to be better adapted to the production of the sugar-beet crop than the other types of soils, the beet-sugar factories in the humid area were generally located in districts where such soils predominate.

For successful production of the sugar-beet crop, the soil should have a good depth, a rather high organic content (the mucks are characterized by their extremely high organic content), adequate drainage, high moisture-holding capacity, and a suitable reaction.

The sugar beet sends its taproot deep into the soil, and any structure that limits the normal and usual depth to which the root can penetrate decreases the volume of soil upon which the taproot and its numerous small feeding roots may draw for the mineral elements and moisture used in growth. Practically all of the soils upon which high yields are regularly produced are found to have a depth of at least 3 feet before there is any change in the structure that prevents the penetration of the roots. If the depth of root penetration is limited by repellent

soil structures, such as hardpan or plow sole, or by a high water table, the resultant roots are very likely to be ill-shaped (fig. 2). On the other hand, if the soil has sufficient depth, the tendency of the sugar-beet plant is to send its roots straight down for a considerable distance. With unrestricted and deep penetration of the taproot, the roots harvested will be long and tapering (fig. 3). Although it is sometimes possible to secure a fair tonnage from a field where soil structure or drainage conditions prevent the beets from making their normal growth of well-formed roots, tare and loss at the factory from tailings are increased in such roots.

FIGURE 3.—A sugar beet of excellent form.

For the production of satisfactory yields the mineral soils[3] should have a fairly high content of humus or organic matter, since this constituent of soil is not only a source of the nutrients but also influences greatly the moisture-holding capacity of the soil and its tilth. The humus content of the mineral soil can be maintained or increased by plowing under legume sods or other green-crop manures at some point in the rotation or by adequate applications of barnyard manure. The organic soils, or mucks, have exceptionally high organic content and consequently a very high moisture-holding capacity.

In the humid districts far greater loss is occasioned by the lack of adequate drainage than is commonly supposed. The significance of

[3] Indicating soils derived from decomposed rock as contrasted with the mucks, or organic soils, and not to be confused with the western soils containing a superabundance of soluble salts.

drainage in securing a stand is discussed on page 42. Lack of drainage limits the depth to which the roots can penetrate and thus limits also the volume of soil upon which the crop can draw for its mineral and moisture supply. In an undrained soil the height of the water table usually varies according to the precipitation received. When a period of low precipitation occurs, the water table may drop so far below the comparatively shallow plant roots that the crop suffers from drought more on such a soil than on a well-drained soil where the roots have penetrated to greater depth. Conversely, in a period of high precipitation more damage is sustained on poorly drained soil, as the water table rises more rapidly than in one that is adequately drained. A few instances have been found of fields that gave good yields where there was a high but fairly constant water table. These yields were possible because of the fact that the stable water table kept sufficient moisture for continuous growth within reach of the roots.

In order to do its best, the sugar-beet crop must grow continuously from the time it starts until within a very short time before harvest. In the humid area, where the crop is produced under natural precipitation, it is inevitable that periods of drought should occur. Although the crop can withstand drought as well as or better than most other cultivated crops, if the amount of moisture held within the soil is insufficient to maintain the crop at a high rate of growth during the drought period, growth lags, and the yield is correspondingly reduced. It is during these periods that the heavier types of mineral soils and the organic soils, with their higher moisture-holding capacities, have a great advantage over the lighter types of mineral soils. Sandy areas in a field or areas with sandy subsoil often are clearly outlined during the heat of the day by wilting of all the beets within such areas, while plants on the adjacent darker or heavier soils show no signs of lack of moisture. The organic matter in the soil, the humus, greatly increases its moisture-holding capacity, and the sugar-beet crop, therefore, seldom suffers from drought so much on soils high in humus as on soils that are low in this important soil constituent. It has also been conclusively established that the quantity of water necessary to produce 1 pound of dry vegetable matter on a productive soil is less than the quantity necessary to produce 1 pound of dry matter on a poor soil. Upon a productive soil the crop is better able to withstand drought than upon an unproductive one. However, the total quantity of water required to produce the higher yield on the productive soil may be more than that required to produce the smaller yield on the poorer soil.

The sugar beet is fairly tolerant to soil reaction. Sugar beets are grown on fairly acid soils and also on soils testing pH 7.5 or more. For the best results it is generally considered that the soil should be about neutral in reaction (7.0 pH) [4] or slightly alkaline. The reaction of the soil influences the availability of the soil nutrients and at least part of the materials that may be applied in commercial fertilizers. If good stands of red clover or alfalfa are secured on a field, this may be taken as indicating suitable soil reaction for the sugar-beet crop. Where these legume crops fail for want of lime, it is advisable to lime the soil prior to planting the beet seed. Waste lime from the beet-sugar factory is generally available at low cost to the growers and, as is shown on

[4] Soil reaction is indicated by its pH; 7.0 pH is neutral. The lower the pH value below 7.0 the more acid is the reaction; the higher above 7.0 pH, the more alkaline.

page 19, compares favorably with liming materials from other sources. Better stands and yields are obtained after a sufficient quantity of lime has been applied to bring about the desired reaction.

ROTATIONS

The desirability of rotating sugar beets with other crops depends upon several factors. Rotation is not an end in itself, but a means to an end; the definite benefits that are derived provide the logical basis for its general utilization in farming. In connection with sugar-beet growing, a properly designed rotation (1) provides for the addition of nitrogen, either from soil-building crops or as manure or fertilizer used with cash crops; (2) maintains humus and rebuilds the tilth of the soil; (3) permits the economical utilization of the condition of the soil as left by the preceding crop; (4) decreases the cost of production by eliminating labor; and (5) protects the crop to a very considerable extent against insect pests, weeds, and plant diseases.

For a mineral soil, a properly planned rotation will include one or more legume or sod crops that add organic matter. If leguminous crops are used, the double purpose of adding organic matter and nitrogen to the soil is accomplished. Of the various soil-building crops, red clover, sweetclover, alfalfa, and soybeans (when plowed under) are the most effective. These are sometimes grown immediately preceding the sugar beets, but preferably as the second crop previous to the sugar beets. If the green-manure crop immediately precedes sugar beets, its maximum effect may not be secured, since the organic matter may not have had sufficient time in which to decay before the sugar beets are planted. There is objection to using either alfalfa or sweetclover immediately preceding the sugar beets, since both of these crops are likely to leave the soil in poor physical condition; and these deep-rooted plants, which are difficult to eradicate, may persist and become weeds in the sugar-beet field. For these reasons, many growers favor the use of the green-manure crop as the second crop preceding the sugar beets, the intervening season giving ample time for the organic material to decay thoroughly and also for the eradication of any of the deep-rooted legumes that may have persisted, as well as to reduce the soil to a desirable tilth. An important objection to using a leguminous crop, such as alfalfa or sweetclover immediately preceding sugar beets, is that in some instances there is greater likelihood of seedling diseases and of insect injury.

The extent of seedling diseases, black root or damping-off, seems definitely to be increased if the sugar beets are planted immediately following alfalfa, sweetclover, or red clover crops. Loss from seedling diseases is greatly reduced if corn, or possibly some other cultivated crop, is grown following the green-manure crop and preceding the sugar beets.

Cutworms and white grubs, as well as wireworms, are often found in grassy, clover, or alfalfa sods, and, if sugar beets are planted immediately following such a crop, insect injury is likely to result. Early fall plowing in this instance will reduce the danger of injury from white grubs, or an intervening crop may be grown in the event that fall plowing cannot be done. The wireworms are slightly more difficult to eradicate, and two intervening cultivated crops may be neces-

sary to eliminate any danger from this source, if the wireworms are known to be present in the grassy sod that is broken up.

In some rotations that have been very successful with sugar beets, heavy applications of barnyard manure are used in place of green manuring. The success of this practice depends, to a very large extent, upon the quantity of barnyard manure that is available, as it requires a relatively heavy application of manure to equal a heavy growth of green-manure crop in supplying organic matter.

The crop succession in a properly planned rotation should be such as to leave the soil prior to planting the beet crop as free from weeds as possible. This feature of the succession deserves special consideration. The sugar-beet crop is a cash crop, and every effort should be made to produce as high yields as possible consistent with cost. The use of soil in which the weed-control problem is lessened eliminates work and secures higher yields, thus increasing the chance of a profitable return.

A well-planned rotation gives ample time between the removal of one crop and the planting of the next for a proper preparation of the soil. It has been demonstrated repeatedly that higher yields (1 ton or more) are obtained on fall-plowed rather than on spring-plowed fields. A cropping system that allows the removal of the preceding crop early enough to permit the fall preparation of the soil for the next year's sugar beets is to be recommended for the humid area.

Definite recommendations for all localities as to the exact crop sequence to use, or even the various crops to use in the rotation, cannot be given. Several that have given satisfactory results are outlined in table 1.

Because of the lateness of the harvest of the sugar beets, the selection of the next crop in the rotation is limited to those that are planted in the spring or early summer. Thus, the spring grains, oats and barley, are very commonly used in this place in the rotation. Experimental work indicates that these crops do very well when following sugar beets as compared with their yields when following other crops or when grown continuously. Corn, when following the sugar-beet crop, also gives a better yield than when grown following corn.

TABLE 1.—*Rotations suitable for use with sugar beets* [1]

Rotation	Year						
	First	Second	Third	Fourth	Fifth	Sixth	Seventh
A	Red clover	Beans	Sugar beets	Barley [2]			
B	Clover	Corn or potatoes.	do	Small grain [2]			
C	Alfalfa	Corn, beans, potatoes.	do	Oats or barley.[2]	Alfalfa	Alfalfa	
D	Sweetclover	Corn	do	Oats [2]	do	do	Wheat.[2]
E	do	Wheat	do	do			
F	do	Potatoes	do	Spring wheat[2]			
G	do	Corn	Soybeans	Sugar beets	Small grain [2]		

[1] With sugar beets sometimes occupying a smaller acreage on the farm than any of the other crops produced, the rotation so far as the sugar-beet crop is concerned may be doubled in length by growing it on one half of the field at one time and on the other half in the next rotation.

[2] Seeded to leguminous crop in the spring or summer.

TILLAGE OF THE SOIL

The object of preparing the soil for the sugar-beet crop, as for any crop, is to secure the highest yields possible that are consistent with economic production. The sugar beet, being grown for the roots, requires, if anything, more attention to the preparation of the soil than most of the other cultivated crops grown. Although the first step in the preparation of the soil for the crop, following the removal of the preceding crop, commonly is plowing, in some instances the plowing is omitted and the soil is prepared by disking. In some dis-

FIGURE 4.—Disking previous to plowing cuts up trash and permits it to be more completely turned under.

tricts the growers follow the practice of thoroughly disking before plowing (fig. 4). The disking cuts up any trash or material that might have been left on the soil by the preceding crop and facilitates good coverage. It has the added advantage of thoroughly pulverizing the surface soil, so that the portion of the furrow slice that is turned down is already in a fine granular state and no large air pockets are left at the bottom of the furrow. Consequently, a smaller number of diskings or operations with a cultipacker or other implement are necessary to firm the soil sufficiently to make a good seedbed and root bed.

The time when the soil should be plowed and the depth of plowing depend, to a very large extent, upon the nature and condition of the soil, the preceding crop, and the equipment available (fig. 5). Shallow plowing is easier and less expensive than deep plowing, but the results obtained with the majority of soils used for the sugar-beet crop are usually in favor of the deeper plowing.

In the sugar-beet-growing districts the soil is usually dry enough during the fall to permit proper plowing, and it is advisable that fall plowing be done, for not only are better yields secured on fall-plowed soils but the soil is likely to contain too much moisture in the spring to permit proper preparation. Deep fall plowing, 8 or 10 inches, on the heavier types of mineral soil is generally entirely practicable, and the

FIGURE 5.—Plowing under a legume sod.

effects of the freezing and thawing during the fall, winter, and spring assist materially in breaking up and mellowing the large lumps of earth that are turned up, thereby reducing the amount of work required in preparing a firm seedbed and a mellow root bed. Were plowing to the same depth attempted in the spring, the preparation of a proper seedbed would be much more difficult. On the other hand, if this type of soil is plowed from 6 to 8 inches deep in the spring, at optimum moisture conditions, less difficulty is encountered in preparing a satisfactory seedbed. With the shallower plowing, the root bed may not be sufficiently deep to permit proper development of the beet root. On

some of the heavier types of soil it is very essential that the plowing be done in the fall, for, with the moisture that is accumulated in the soil during the winter and spring, it is practically impossible to perform the necessary preparatory work and still keep the soil in good physical condition. Such soils, plowed in the fall and reduced by freezing and thawing, can be satisfactorily prepared for planting by the very lightest of surface working.

Soils of the lighter-textured mineral types may usually be plowed to the same depth in either the fall or the spring and with less regard

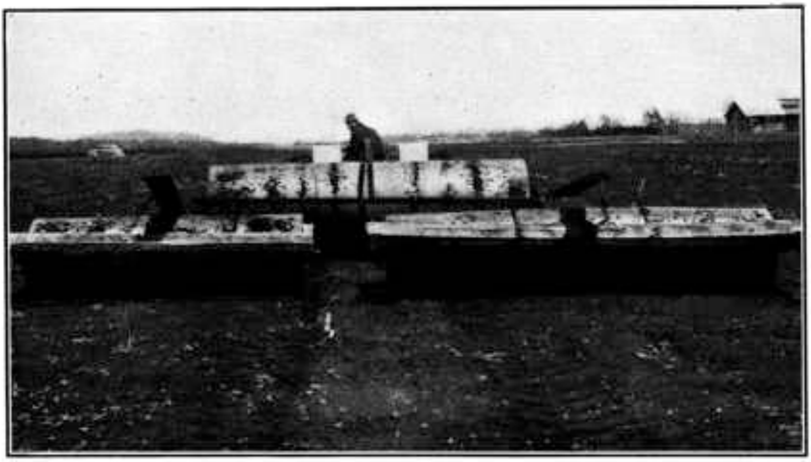

FIGURE 6.—Rolling muck soil to compact it prior to planting sugar beets.

for the moisture content of the soil, without encountering any great difficulty in the preparation of a good seedbed and root bed. Fall plowing should not be practiced with those lighter soil types and with a few of the heavier types in which the effect of the freezing and thawing is such that the structure is broken down and the soil is nearly as compact in the spring as it was in the fall before plowing.

The methods used to prepare the muck soils for the sugar-beet crop, or for any crop, differ radically from the foregoing methods. Very often the muck soils are so loose that all tillage operations are designed to compact the soil (fig. 6). Even if it is deemed necessary to plow the muck soil, more work is necessary to firm such a soil than is ordinarily necessary with the loosest types of mineral soils. Plowing muck soils also often turns up large numbers of weed seeds that increase the difficulty of caring for the crop.

Following the plowing of a mineral soil, when it is sufficiently dry so that it can be worked without becoming compacted or cloddy, whether the soil is light or heavy and whether the plowing is done in the fall or in the spring, the soil is usually thoroughly disked (fig. 7) and dragged with a spring-tooth harrow. The weighted disk when set nearly straight shatters the solid pieces of the furrow slice that have not fallen apart and stirs the soil so that the finer and looser material has an opportunity to move downward and fill the crevices and voids between the larger lumps and between the furrow slice and the bottom of the furrow. The spring-tooth harrow stirs the soil

thoroughly, permitting further downward movement of the fine material, and also works the larger clods and unbroken pieces of the furrow slice to the surface, where they can be reduced more easily. Following the disking and the spring-tooth harrowing—and these operations may be performed once or more, according to the condition of the soil—the cultipacker, or clod crusher, is generally used to crush lumps or clods that have been brought to the surface and to firm the soil (fig. 8). When rightly prepared, the root bed is firm enough so that a person can walk on it without sinking much over one-half inch; yet

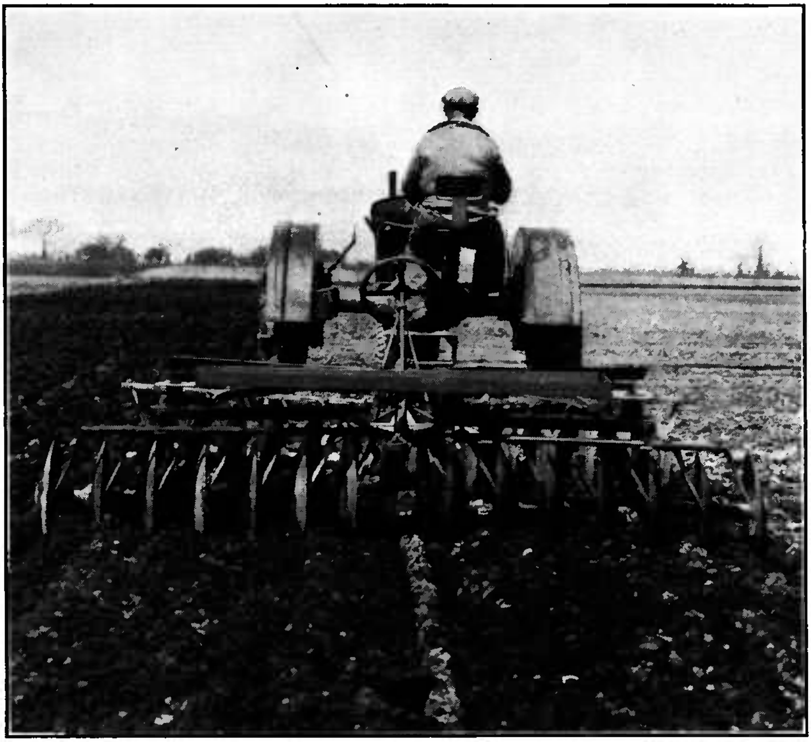

FIGURE 7.—A disk is used to cut the furrow slice and break large soil blocks after the soil is plowed.

it is mellow enough to permit the roots to develop normally. If the root bed has not been stirred to a sufficient depth, or if it has been rendered too compact by the various operations, deep penetration of the soil by the taproot is hampered.

Following the initial work of preparing the seedbed and root bed, some of the growers wait a few days before performing the final operations, as this permits many of the weed seeds to start germination, and the final work in the preparation of the seedbed eliminates them.

The object of the final work in the preparation of the soil is to level the surface and reduce the subsurface to such a state of granulation that the seed can be planted to a uniform depth and be in close contact with firm, moist soil. On some soils, where there is no danger of crusting, the entire surface may be reduced to a very fine granular

state, but on some soils of the heavier types it has been found to be a distinct advantage if the soil surface is left covered with small clods up to 1 inch in diameter, as these prevent crusting, while the subsurface has been reduced to the necessary fine granular state that facilitates rapid germination of the seed.

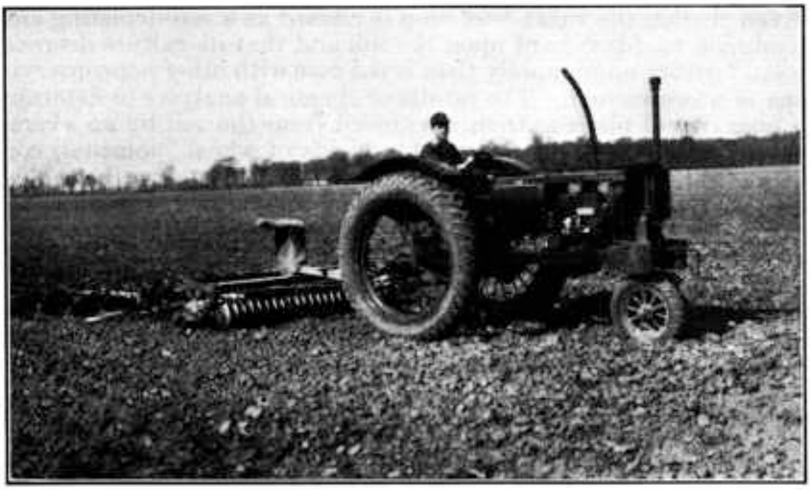

FIGURE 8.—A cultipacker or clod crusher used to reduce the soil to the desired degree of firmness and fineness for a good seedbed.

Many of the growers with large acreages have adopted a plan in which the soil is worked to a point where one final set of operations in the preparation of the seedbed will finish it. Then, starting on one side of the field, the disk, spring-tooth harrow, cultipacker, and sometimes the smoothing harrow or spiked float, operating one after

FIGURE 9.—Completion of final operations of soil preparation as shown above, immediately before drilling in of the seed, avoids loss of time and labor if rain should interrupt the work.

the other (fig. 9), are used to finish the preparation of the seedbed and are immediately followed by the drills. The advantage of this plan is that if the work is interrupted by rain, the seed has already been planted on that portion of the field that has been finished, and the work performed in the final preparation of the seedbed is not lost. On small acreages, or where the entire field is prepared before drilling

begins, if the last harrowing is given at right angles to the direction in which the beet rows are to run, so that the marks left by the implement will not be confused with the drill mark, drilling can be done more accurately.

PLANT FOOD REMOVED

Even though the sugar-beet crop is classed as a soil-depleting crop, the opinion that it is hard upon the soil and that its culture decreases the soil fertility more rapidly than is the case with other nonconserving crops is unwarranted. The results of chemical analyses to determine the quantity of plant nutrients removed from the soil by an average crop of sugar beets and comparable yields of wheat, potatoes, corn, barley, field beans, red clover, and alfalfa hay are given in table 2. These analyses do not furnish any basis for stigmatizing the sugar beet as a "soil robber." No matter what crops are grown, it must not be expected that a soil can continue to produce good crops indefinitely without the use of fertilizers to maintain a proper fertility balance and to replace plant nutrients that have been removed. In the humid area it should be a general practice to apply fertilizer for the production of ordinary crops whether sugar beets are grown or not.

TABLE 2.—*Plant nutrients removed from the soil by an average crop of sugar beets and the quantities removed by comparable yields of other crops* [1]

Crop	Yield [2]	Nitrogen	Phosphoric acid	Potash
	Tons	*Pounds*	*Pounds*	*Pounds*
Sugar beets, roots only	8	42	14.4	53.0
	Bushels			
Wheat, grain only	20	25	12.1	6.4
Corn, dent, grain only	30	26	10.8	6.7
Barley, common, grain only	25	23	10.5	7.6
Beans, field, seed only	12	26	7.4	10.1
Potatoes, tubers only	100	21	6.6	32.4
	Tons			
Red clover hay	1.3	49	10.7	49.0
Alfalfa hay	1.66	78	15.9	80.7

[1] Based upon data given in Morrison's Feeds and Feeding, twentieth edition, 1936. The analyses for phosphorus and potassium are given as phosphoric acid and potash.
[2] Based upon the approximate average yields for Michigan.

USE OF FERTILIZERS IN BEET ROTATIONS [5]

Barnyard manure is perhaps the most common as well as the best fertilizer to use with the sugar-beet crop in almost all localities in the humid area where sugar beets are grown. Not only does the manure application increase the organic content and moisture-holding capacity of the mineral soil, but it also supplies nitrogen and some of the mineral elements that the plants use. On organic soils or mucks the application of barnyard manure often increases the desirable bacterial activity within the soil, thereby increasing its productiveness. The quantity of manure is generally limited by the quantity that is produced on the farm. From 6 to 10 tons per acre are commonly applied. The heavier applications are not always given immediately preceding

[5] Tests on fertilizers to be used with sugar beets are conducted in cooperation with the Division of Soil Fertility Investigations, Bureau of Plant Industry.

the cropping of a field with sugar beets, for it is often found that greater benefit is derived by adequately manuring some cultivated crop immediately preceding sugar beets; in such a practice, the manure may be applied to a legume sod or a green-manure crop before plowing it under. In this way ample time is given for organic matter to become incorporated into the soil, and weeds that may have been carried onto the field in the manure may be controlled in the preceding cultivated crop.

Commercial fertilizer is generally used with the sugar-beet crop, and in the rotations where sugar beets are grown this crop ordinarily receives a much heavier application of fertilizer than the others in the rotation. The amount of fertilizer applied to sugar beets varies widely. In those districts where the crop is relatively new the rate of application is not so great as in those districts where it is an established part of the farming system. In the newer districts applications vary from small amounts to as much as 250 pounds per acre. In the long-established districts 500 or 600 pounds per acre and occasionally even more is applied.

FERTILIZER PLACEMENT [6]

Studies are being made to determine which placement of the fertilizer will result in the most efficient utilization of the added plant-food material by the sugar-beet plant. Results obtained to date have not definitely indicated any one particular placement as resulting in the most efficient use, but the trend of the results indicates that the fertilizer should be placed close to and slightly below the seed.

Especially where the heavier applications of fertilizer are used, many of the growers follow the practice of broadcasting a large portion of the fertilizer either before or during the preparation of the soil, the remainder being applied in the row with the seed when the crop is planted. The broadcasting is usually done with a grain drill. If the fertilizer is broadcast before the soil is plowed, it is spread on the surface shortly before plowing and is then plowed under. If the broadcasting is done after the soil is plowed, the fertilizer is drilled in as deeply as possible (fig. 10). Where part of the fertilizer is broadcast any appreciable length of time before the crop is to be planted, many of the growers who follow this practice prefer to apply a fertilizer containing only phosphoric acid or phosphoric acid and potash, later applying a complete fertilizer in the row with the seed. In some districts, additional fertilizer, especially nitrogen, may be applied early in the cropping season as a side dressing.

The amount of fertilizer that is drilled in the row with the seed varies somewhat but does not generally exceed 200 pounds. Ordinarily, no provision is made to keep this fertilizer from coming in direct contact with the seed. Special drill shoes are now on the market by which the fertilizer applied at seeding time is deposited either in a single band beside the drill row, or in two bands, one on each side of the row, either method serving to separate the fertilizer from the seed by a small amount of soil. Dividing the fertilizer in this manner may be expected to decrease the possibility of fertilizer injury during the germination

[6] Tests on fertilizer placement are being made in cooperation with the Division of Soil Fertility Investigations, Bureau of Plant Industry, the Division of Mechanical Equipment, Bureau of Agricultural Engineering, and the Ohio Agricultural Experiment Station.

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of the seed. Experience has established the fact that fertilizer injury is not likely to be sustained except under certain conditions. If very dry soil conditions prevail in the germination period, seedling injury or some retardation of germination may be caused by the fertilizer applied in contact with the seed. Heavy applications of mixtures containing more than four units of nitrogen, if in contact with the seed, may burn the seedlings. Superphosphate has been applied with the seed in amounts as high as 600 pounds per acre without interfering in any manner with the germination of the seed and the growth of the seedlings. To avoid possible delay in germination or injury to the seedlings, the growers who apply the larger amounts of fertilizer usually

FIGURE 10.—Drilling in fertilizer deeply with a grain drill, following plowing and prior to final soil preparation for planting.

broadcast the greater portion and apply a smaller portion, usually not exceeding 200 pounds, in the row with the seed. The improved devices mentioned for placement of fertilizer should make this additional operation unnecessary.

With the advent of the hill-drop and checkrow drills that place the seeds in small groups at spaced intervals in the row, it may be found advantageous to place the fertilizer, which is ordinarily put in the row with the seed, in broken bands beside the row and opposite the seed groups instead of having it distributed continuously along the row.

When fertilizer is applied as a side dressing (fig. 11) following blocking and thinning it is cultivated in with special attachments on the cultivator. These attachments are designed to place the fertilizer at a sufficient depth, 2 to 6 inches, so that it will be in moist soil in the active root zone. It may be placed on either side of and a few inches from each row, but a simpler method, which possibly is not so efficient, is to make one application in each middle between the rows. The application of fertilizer at this time and in this manner is not general, but it may be of advantage under conditions where the crop needs a stimulant or where the foliage conditions indicate a cessation of growth.

Consequently, the fertilizer that is used in this manner is usually entirely nitrogenous or highly nitrogenous, the amounts varying from 100 to 300 pounds or more per acre.

FERTILIZER MIXTURES

The fertilizer mixture that gives the best results depends upon the soil and the farming system followed. Muck soils give best results usually when the mixture contains a very high proportion of potash, while the mineral soils require a greater proportion of phosphorus.

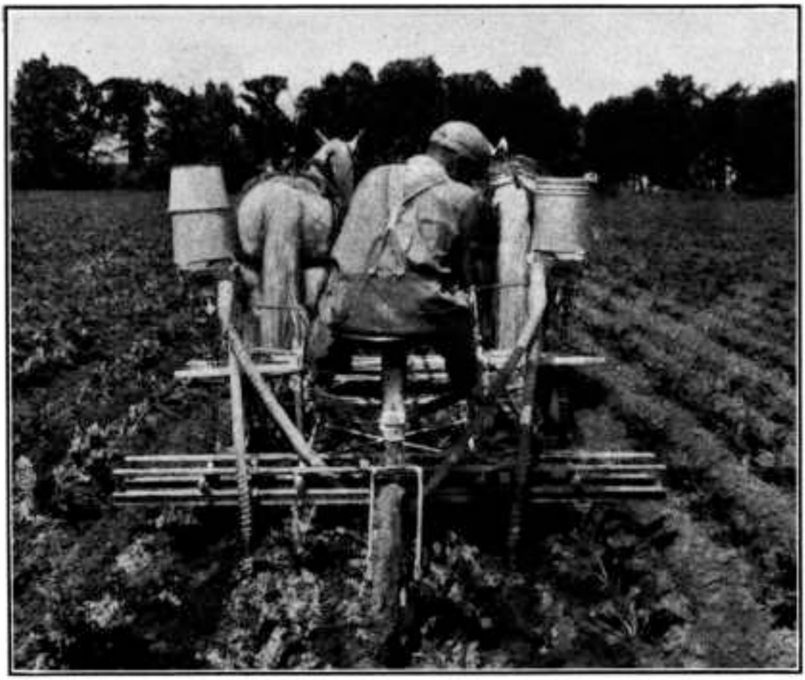

FIGURE 11.—Additional fertilizer being applied as a side dressing during the cultivation of young beets.

The lighter mineral soils are more often found to be deficient in both nitrogen and potash than the heavier, darker types. For use with the lighter soils, the mixture ordinarily should contain more nitrogen and potash, in proportion to the phosphoric acid, than mixtures intended for the darker, heavier soils. Yet for both classes of mineral soils a higher proportion of phosphoric acid than of either nitrogen or potash is necessary (fig. 12).

The more liberally the soil has been fertilized with barnyard manure, green-crop manures, and legume sods, the less will be the need for applying nitrogen and potash in fertilizer form. Where little manure and no green-crop manures have been used and where legume sods have not been broken up regularly, it will be found necessary to apply larger amounts of nitrogen and potash in proportion to the phosphoric acid in the fertilizer, to obtain comparable results.

Experimental work indicates that poor returns are obtained and that actual loss may result from applying a fertilizer mixture that does not fit the soil. The findings also indicate that the fertilizers have an appreciable effect on the quality of the sugar beets, although this effect is less pronounced than that upon yield.

The grower should seek to determine the appropriate fertilizer treatment to apply from specific consideration of the field in question, from experience with the response of other crops, especially corn, to the fertilizer elements, and by direct comparison with the results of local experiments.

FIGURE 12.—Excellent growth in the fertilized portion of the field (right and left), in striking contrast with that of the four unfertilized rows (center).

SOIL AMENDMENTS

Soil amendments are materials, which, when applied to the soil, may not furnish necessary plant nutrients themselves, but influence the soil in such a manner that the crops are better able to utilize the plant nutrients that are already within the soil or that may be applied in the form of commercial fertilizers, and therefore become more profitable.

LIME

Application to the soil of calcium carbonate, as finely ground limestone or hydrated lime or in other form, is the most common of all soil treatments. Soils are limed (fig. 13) primarily to correct soil reaction, but the lime has other beneficial results.

Soils in the humid area tend, under continued cropping, to become more acid in reaction. As has been previously stated, the sugar beet does best with soils about at the neutral point or slightly alkaline. Fields are not commonly limed immediately prior to planting the

beet crop, since, in a proper rotation system for sugar beets, enough soil-building crops are grown so that periodically sugar beets return to fields where such crops have recently been grown. As is well known, success in growing alfalfa and clovers on soils that tend to become acid requires attention to the correction of soil acidity by liming. With an adequate rotation system, the sugar-beet farmer each year can provide for the beet crop an acreage whose soil reaction has been corrected as necessary.

In the process of sugar manufacture, a large amount of limestone is employed, amounting approximately to 6 percent of the weight of the roots sliced. The spent lime is finally discharged into settling

FIGURE 13.—Liming soil with waste lime from a beet-sugar factory.

basins near the factory, where it accumulates. Sometimes it is removed from these basins and piled (fig. 14). It has value for agriculture chiefly as a material for liming. This supply of lime cake, factory lime, or waste lime, as it is variously called, is an important factor in meeting the soil-liming problem. Table 3 gives the analysis of this lime in pounds per ton of the various constituents and shows that the lime content ranges from 59 to 71 percent. Since factory lime or filter-press (lime) cake is readily available, the maintenance of the farm at optimum soil reaction can economically be accomplished. Full advantage of this source of lime should be taken by the beet farmer.

TABLE 3.—*Composition of filter-press (lime) cake, expressed in pounds per ton*[1]

[Basis of 20-percent moisture in cake]

Constituent	Average	Maximum	Minimum
	Pounds	*Pounds*	*Pounds*
Potash	3.2	8.8	1.3
Phosphoric acid	8.8	15.5	5.1
Ammonia	4.5	6.7	2.2
Calcium carbonate	1,324.2	1,429.8	1,183.0
Organic matter (approximate)	154.6	230.7	59.4

[1] From U. S. Dept. of Agr. Circular 257, 1923, Composition of Filter-Press (Lime) Cake.

COMMON SALT

Recently the old practice of applying salt to fields prior to cropping with sugar beets has been revived. The fairly consistent showing in certain Michigan districts that higher yields were obtained where

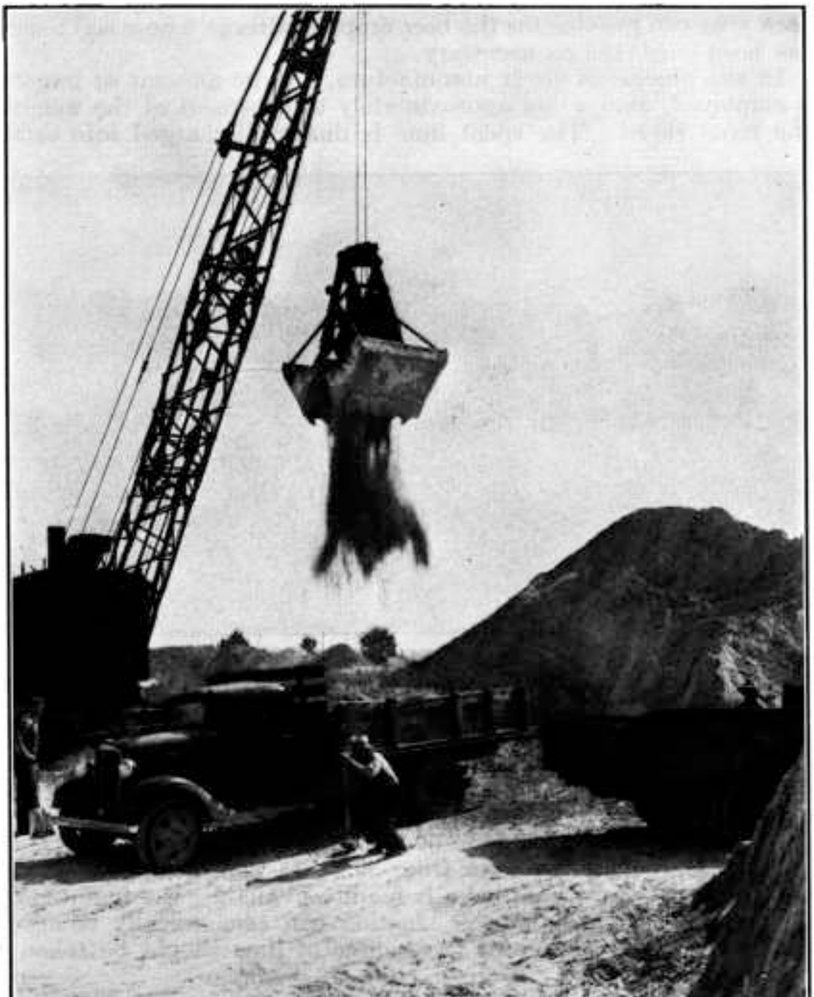

FIGURE 14.—Waste lime from the beet-sugar factory. This is available to growers for use in correcting soil acidity.

salt was used, together with some evidence that stands were better, has resulted in its rather widespread use.

Salt in these districts is available at low cost. For mineral soils, the amounts used have ranged from 200 to 1,000 pounds per acre, the average application being 500 pounds. For muck soils, the amount used has been larger. Applications have usually been made by broadcasting during soil preparation.

Chemical studies have indicated that salt applications lower somewhat the quality of the beets. The molasses-forming properties of the juice probably are increased, which may interfere with recovery of sugar in the factory.

General recommendation for use of salt on sugar beets is not made. The experience extending over several years in the districts employing this practice has not indicated deleterious effect on soil texture. Adverse effects on the crops that follow in fields to which salt has been applied have not been observed. Common salt must, however, be considered as a soil amendment whose use is to be restricted to those sections in which definite benefit and absence of harmful aftereffects can be shown.

OTHER NECESSARY FERTILIZER ELEMENTS

Recent studies have shown that in addition to the usual fertilizer elements, nitrogen, phosphorus, and potassium, plants require a great many other elements for normal growth. These elements, such as iron, copper, magnesium, manganese, boron, arsenic, and others, are commonly but not always present in the soil in the very small quantities necessary for crops. The ordinary commercial fertilizers may carry some of these elements, either as impurities or as elements intentionally added by the manufacturer. Where, however, any of these essential elements, frequently spoken of as "minor elements," because of the small quantity required in plant life, are deficient, profound effects are produced. These manifest themselves in abnormal plant growth and reduced yield and quality.

Applications of salts of copper, magnesium, manganese, and boron have been found in some districts to aid in crop production and to improve the quality.

The most striking effects have come from applications of boron (usually as borax) to fields known to be deficient in this element. A deficiency of boron in sugar beets is evidenced by a blighting of the inner unfolding leaves of the plant and by flesh discoloration of the roots. Affected plants lose their tops, and small accessory buds on the crown start feebly, making the plants look as if injured by trampling. The death of the tops and flesh discoloration may lead to a dry rot of the roots. The leaf symptoms commonly show up in the field in late July and August and seem correlated with dry soil conditions. Boron deficiency has been found more often in the lighter-textured, more gravelly soil types than in the heavier, darker types.

Boron deficiency manifesting itself in sugar beets can be corrected by applications of not to exceed 15 pounds of borax per acre. Finely granulated borax, mixed with dry sand to aid distribution, may be broadcast during the preparation of the field. It must be understood that many crop plants may be injured by boron additions that sugar beets could tolerate. In correcting a known boron deficiency, care must be exercised that a harmful amount of boron is not built up in the soil. Borax applications should be given preferably under the supervision of the State agricultural experiment station, county agent, or beet-sugar company fieldman.

Copper, as copper sulphate, gives beneficial results on most muck soils, and the amount ordinarily recommended is from 25 to 50 pounds per acre. Magnesium, as magnesium carbonate (as in dolomitic

limestone), is found to be of benefit on some of the lighter-textured mineral soils, although sugar beets are not often grown on these soil types. Manganese, as manganese sulphate, has been used experimentally with the sugar-beet crop, and it has been determined that, on some mineral soils, roots higher in sucrose percentage and juice of higher purity result when it is used.

MARKETING THE SUGAR-BEET CROP

Aside from its possible use for cattle feed on the farm, the sugar-beet crop can only be marketed at a beet-sugar factory, which, in turn, must make the salable product, sugar. The manufacture of sugar from sugar beets is a complicated chemical process in which sucrose is extracted from the slices of the beet, purified, and finally crystallized as the sugar of commerce. Establishing a beet-sugar enterprise involves a large capital outlay, and the agricultural conditions must be such as to give assurance that the undertaking is feasible. Prior to launching a project it is necessary to determine that adequate acreage of adapted soil is available within economical transportation distance and that the sugar beet will fit into the types of farming practiced. Because of the efficient use of byproducts, sugar-beet growing fits well with dairy farming or livestock feeding. Other factors, such as available labor supply, should be taken into consideration. The requirements for optimum growth of the sugar beet, as outlined on page 3, cover in general the agricultural conditions that are prime essentials for such an undertaking.

The farms on which sugar beets are grown must be located within economical shipping distance of a factory. Many farmers in the humid area of the United States where the culture of sugar beets is possible cannot undertake the growing of this crop because there is no factory near enough to serve as an outlet.

In contrast to other important field crops, the sugar beet is always grown under contract with a beet-sugar factory. Sugar-beet contracts are entered into yearly by the grower before the crop is planted and carry stipulations as to the acreage to be grown, planting, care, harvest, and crop delivery. The factory agrees to supply the beet seed at a stipulated price and to accept the crop grown if it meets certain minimum quality requirements when delivered. At the beginning of the harvest season the deliveries may be limited, but in midharvest or before, limitation on delivery is removed.

The contracts in some cases name a flat rate, commonly dependent upon sugar price, to be paid for sugar beets of a stated quality delivered to the factory. In other districts the contracts are of a participating type in which the net returns from the sale of sugar, pulp, and molasses are divided between processor and growers upon some percentage basis (as, for example, in 1937, 50–50). The grower's portion of the return is subdivided among the individual growers pro rata according to tonnage produced. Under this contract, the grower's obligation is to produce the sugar beets and deliver them to the factory, and the factory's obligation is to process the beets and market the sugar, pulp, and molasses. Certain costs for selling are allowed in determining the net returns.

Under the Sugar Act of 1937, a tax is levied on each 100 pounds of recoverable sugar produced, and provision is made for benefit pay-

ments to farmers who comply with provisions of the act as to acreage, soil-conserving, fertility-improving, erosion-prevention practices, nonemployment of child labor, and rate of labor payment. A prospective beet grower should consult the representatives of the beet-sugar factory as to details of the contract offered, and he should secure from his county agent information as to current Federal regulations applicable to the sugar-beet crop.

MACHINERY AND LABOR REQUIREMENTS

Special implements adapted to handle this root crop, which is grown in rather closely spaced rows, add efficiency in performing many of the required operations. The implements used in soil preparation are

FIGURE 15.—Combination implements used for preparing the seedbed.

the general-purpose ones suited to a given acreage to be handled, supplemented by such leveling or compacting devices as are needed for the beet crop. Drilling and cultivation, while possible of accomplishment by ordinary equipment, commonly are done with special beet drills and cultivators capable of handling four or more rows at a time. Lifting of beets at harvest is done more efficiently with a special beet plow which breaks the taproot off deep in the soil and then loosens and lifts it slightly.

The development and widespread use of the tractor has brought about decisive change in sugar-beet machinery. Low-capacity implements have been replaced by gang plows, combination implements for seedbed preparation, multiple-row seeders, and cultivators (figs. 15, 16, and 17). Utilization of such increased-capacity machines on the larger acreages has made it possible to perform the operations of preparation, planting, cultivation, or lifting more quickly and at lower costs per acre.

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In Iowa and Minnesota districts especially, the use of hill-drop (fig. 18) and checkrow drills has eliminated the hand work formerly entailed in blocking and has speeded up thinning operations. Fields

FIGURE 16.—Six-row sugar-beet drill with attachments for applying fertilizer with the seed.

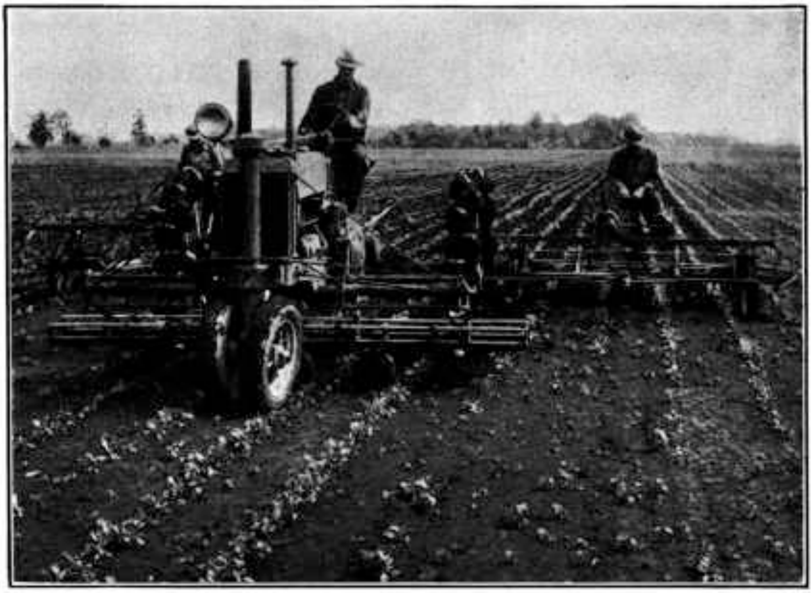

FIGURE 17.—Multiple-row cultivator in operation.

planted with a checkrow drill may be cross-cultivated, and, ordinarily, hoeing is not necessary. Similarly, cross blocking is widely practiced in these districts when stands are adequate (fig. 19). This is done

by cultivating at right angles to the row. The cultivator, properly equipped with knives, cuts out all plants except those in small blocks properly spaced with respect to adjacent blocks (fig. 20). In this

FIGURE 18.—Field planted with a hill-drop drill.

FIGURE 19.—Beet cultivator with cutting tools arranged for cross blocking.

way, the necessity for hand blocking is avoided, and the thinning of the blocks can more easily be done. As the plants are cut out, weeds in the row are also eliminated, reducing the cost of hand hoeing.

Studies conducted in Michigan[7] show that the total number of hours of labor required to produce an acre of sugar beets has decreased from an estimated 125 hours in 1915 to 99 in 1935. The estimate of 50 hours of machine labor employed in 1915 was reduced to 29 in 1935. A considerable part of this decrease in labor required has come about from motorized machinery. The greater efficiency, which has come

FIGURE 20.—Sugar-beet field after cross blocking. (Photographed at right angles to direction of drilling.)

from the substitution of the autotruck for the team and wagon to haul the crop from field to factory or loading station, is obvious. The use of machines of greater capacity for land preparation and other operations has also contributed to this reduction. While this reduction in labor hours for machine operations was being accomplished, the hand-labor requirements were estimated as dropping from 75 hours per acre to 70.

Such changes as have become established have already reduced production costs. Even fuller mechanization of beet-growing operations is forecast, if the development of mechanical blockers, mechanical thinners, and harvesting machines (lifters, toppers, and loaders) continues. These, however, are as yet in the early field-trial stage.

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[7] MACY, LORING K., ARNOLD, LLOYD E., MCKIBBEN, EUGENE E., and STONE, EDMUND J. CHANGES IN TECHNOLOGY AND LABOR REQUIREMENTS IN CROP PRODUCTION. SUGAR BEETS. 48 pp., illus. 1937. (Works Progress Administration, Studies of Changing Techniques and Employment in Agriculture, Rept. A-1.)

SUGAR-BEET SEED

The sugar-beet seed (fig. 21) as furnished the grower is not a true seed, like a pea or bean, but is a seed ball, or glomerule, composed of the dried flower parts and enclosed seeds of several flowers whose

FIGURE 21.—Sugar-beet seed (approximately natural size).

basal portions are grown together. At maturity the floral parts dry, and the germs (true seeds) lie free within the ovary walls. At germination the lids (upper portions of the ovaries) loosen, and each viable germ develops into a seedling. With seed balls screened to medium size, the number of seedlings is about two or three from each seed ball; larger seed balls produce four, five, or even more seedlings.

Seed-ball size varies, being influenced by conditions under which the seed is produced, such as the density of the planting of the mother roots and soil fertility. Ripening proceeds from the base to the tip of the floral spikes and is indeterminate. Some seed balls may be fully matured and ready to shatter at harvest, while some are still immature. In the cleaning process, the immature and very small seed balls are removed by fanning and screening, those passing over

FIGURE 22.—Isolated seed plot in which an improved variety of sugar beets, adapted to American conditions, is being increased to produce planting stock of this variety.

a 2-millimeter slotted screen being acceptable according to the Magdeburg standards, under which European seed is sold. Domestically produced seed is commonly screened to a somewhat larger size as a minimum. With comparable viabilities, size of seed ball has not been found greatly to affect stands. The number of seed balls dropped per row by the drill is governed by the seed-ball size. With a uniform setting of the drill, approximately the same weights are planted, irrespective of size. Correlation of seed-ball size and vigor has not been shown. Practically the same acre yields of roots and of sugar have been obtained from the small, medium, and large seed balls screened from a given seed lot.

Until very recently, practically all sugar-beet seed was imported from Europe. Beginning in 1932, with the introduction by the United States Department of Agriculture of varieties improved in curly top resistance for use in western districts where this disease occurs, home production of sugar-beet seed, not only of curly top-

resistant varieties but of other improved varieties, has increased by leaps and bounds. The amount of sugar-beet seed grown in 1937 was adequate to supply all the curly top area and provide a considerable reserve. In addition, nearly enough seed of sugar-beet varieties improved in leaf-spot resistance or other qualities was produced to meet the requirements of the Mountain State and Midwestern areas. The 1937 sugar-beet-seed crop reached a total of more than 12,000,000 pounds. Considering the acreage as a whole, and allowing for reserve supplies produced, the domestic sugar-beet-seed industry supplied about 70 percent of the seed planted in 1938. It is expected that, as the seed-production problems are met, growers in the humid area can also be supplied with home-grown seed.

Sugar-beet varieties (fig. 22) have already been produced by the Department of Agriculture that are highly resistant to cercospora leaf spot, the disease that caused severe damage to the crop in the humid area in 1935 and 1937. These improved varieties, produced by modern methods of disease-resistance breeding, have reached a point where they compare favorably with the average European brands in ordinary seasons and outyield them in both tonnage and sugar under leaf spot conditions.

The individual grower necessarily depends upon the beet-sugar company to keep in touch with Federal and State tests of improved varieties and to conduct tests to determine the varieties best adapted to the district. The companies realize the necessity for supplying high-grade seed of improved varieties, and the growers' associations may very well interest themselves in the improvement of sugar-beet varieties now taking place, so that no lag occurs in supplying growers with the best-adapted sorts.

PLANTING

Being an intertilled crop, the sugar-beet crop is planted in rows. For this purpose, drills of various types and makes are used. Some of the drills plant the seed in a continuous row, some place it in hills at definite intervals, and some checkrow the field. The space between rows used in the humid area has steadily been narrowed during the past several years, until at present it ranges from 18 to 24 inches, with the greater portion of the acreage being planted in rows that are either 20 or 22 inches apart. In some instances the seed is planted with an ordinary grain drill in which every third hole is left open. This spaces the rows according to the fixed adjustment of the drill, usually 21 inches apart. The use of paired rows is becoming more and more common. By this method the rows are in pairs, either 14 or 16 inches apart, with a wider space, either 26, 24, or 22 inches, between the pairs (fig. 23). This maintains the space allotment per plant at the desired point and affords wider rows in which the team or tractor may travel.

The quantity of seed to use per acre for the best results depends upon the climatic and soil conditions and the spacing of the rows. In general, the beet-sugar companies recommend that from 17 to 20 pounds of seed be used per acre, but with the hill-drop and checkrow drills a proportionately smaller amount is needed.

If the seedbed has been properly prepared and there is sufficient moisture in the soil to germinate all the seeds, a solid stand along the drill rows will be secured at the above planting rates. The use of the

quantity of seed recommended does much to compensate for losses of seedlings if weather conditions are not optimum or if damping-off is prevalent.

The initial stand is thinned drastically, leaving only one beet at each 10- or 12-inch interval in the row. One or more sturdy seedlings every 2 inches in the row may be considered a good initial stand. Good distribution along the drill row affords a full stand after thinning.

DEPTH

Many failures in securing a stand of sugar beets have been blamed upon improper planting depth. Experiments indicate that there is a considerable range as to the depth to which the seed may be planted

FIGURE 23.—Sugar beets planted in paired rows. This arrangement affords wider spaces in which the team or tractor may travel.

without materially affecting the stand secured. The soil should be warm enough for the seed to germinate readily after it is planted, and, since there is considerable difference in soil temperatures at different depths early in the season, the earlier plantings may be relatively shallow—from one-quarter to three-quarters of an inch. With the later plantings, when the soil has warmed to a greater depth and the surface has dried, a depth of 1 to 1½ or even 2 inches is recommended, depending upon the compactness of the soil and moisture conditions. With these later plantings, which are made to a greater depth, when the surface soil remains loose the seedlings have little difficulty in breaking through, but in case of heavy rain before the seedlings emerge there is danger of a crust forming that they cannot break. If the field work to counteract crusting is tardy and the seedlings are held in the crust, disturbance of the soil is likely to break the plants and kill the seedlings (p. 33).

TIME OF PLANTING

For the best development of the crop, the sugar-beet plant should be given as long a season as possible in which to grow. Observations and experiments in the humid area indicate that the period in which the sugar-beet crop may be planted extends from the middle of April to the middle of May, but it has been demonstrated time and again in commercial fields and also on experimental plots that the higher yields are obtained from the earlier rather than the later plantings.

The sugar-beet plant will continue to grow as long as conditions are favorable, and the total increments of plant substance become progressively greater as the plants grow older and have more foliage. Thus, the quantity of sugar formed in a single day in the latter part of the season is many times that which is formed in a day or a week early in the season. The differences in yields obtained from early plantings not only represent the differences in the amount of growth made early in the season but represent also greater formation and storage of food reserves from the larger plant unit. The accumulation of food reserves, chiefly sugar, is checked by climatic factors or necessity of harvest. In order to take the fullest advantage of the climatic conditions that permit the most effective sugar production, early planting is recommended.

THINNING

Because of the fact that the seeds cannot be planted singly, being contained within the seed balls, and to assure proper distribution of plants as described, an excess of seed is used, and the initial stand of seedlings must be thinned to a proper stand before there is much competition among them.

An experiment carried on at the Michigan Agricultural Experiment Station, in which the seedlings were thinned at weekly intervals from the time the crop could be "rowed through"[8] until the end of the seventh week thereafter, furnishes some information as to the best time to thin. The results showed a decrease in yield for each week's delay in thinning after the end of the second week. The size of the beets at the end of the second week after rowing through usually coincides with what might be termed the small "four-leaf" stage. There are, however, certain conditions that may make it inadvisable to thin the beets between the first and the third week after rowing through. In the event of adverse growing conditions, the beets may not reach the proper stage for thinning in the same length of time they did in this experiment, where the growing conditions were comparatively favorable. In case germination has been uneven, seedlings may still be emerging from the soil, and it may be necessary to delay thinning so that all excess seedlings may be removed at one time. In fields where seedling diseases are killing a large number of the plants, it is a good plan to wait until diseased plants can be readily distinguished from the sturdy, healthy ones.

It is not always possible to thin a commercial field of beets at just the proper time on account of labor conditions. In those districts where the favorable planting season is very short, it is often desirable that a large acreage be planted at one time. Under these conditions it has been found that hill plantings, as with checkrow drills or cross

[8] The term "rowed through" is used to indicate the condition when the row of beet seedlings can be followed with the eye for several hundred feet. This stage, when the true leaves are just starting, is taken as the basis because it is the earliest stage at which thinning can be done.

blocking of continuous-row plantings, are valuable in speeding up the job of thinning before competition among the seedlings and weed growth becomes serious.

Growers usually secure the labor necessary for blocking, thinning, and other operations at a contract price per acre. The work is done according to certain standards; but it always should be closely supervised by the farmer, because the crop that will be produced largely depends upon the securing of proper stands after thinning.

At thinning time some of the seedlings will be large and flourishing, while others may be small and spindling. In order to determine the influence that the comparative size of seedlings may have on the yield and sugar production, records were obtained from adjacent plots on which the largest and the smallest seedlings, respectively, were left to grow. The results obtained indicated that there is a very considerable gain resulting from retaining the larger plants.

Where the seed is drilled continuously in the row and cross blocking with the cultivator is not employed, the thinning of the plants to leave one in a place properly spaced from its neighbors is done either as one or as two operations. Certain laborers prefer to block and thin with a short-handled hoe, going over the row once to complete the singling and cutting out of small weeds around the plant. In other cases the row is blocked by means of a long-handled hoe by one laborer, who seeks to leave a few seedlings standing undisturbed at about the proper row interval. The extra seedlings and all weeds are then removed by a second laborer.

The use of hill-drop (fig. 18) and checkrow drills or the cross blocking (fig. 20) of the continuous rows with the cultivator eliminates to a very large extent the work that is necessary in blocking the beets. Moreover, these machines so regularly space the groups of seedlings that the final spacing of the beets left at thinning is much more nearly regular than if hand labor had performed the entire operation. In thinning the beets where the field has been planted with a hill-drop or checkrow drill or where the field has been cross blocked the thinners are sometimes equipped with short-handled or special hoes, and the work of removal of extra seedlings and weeds from each group of beets is reduced.

SPACING THE PLANTS

The individual sugar-beet plant should be given sufficient space to secure the best results from the crop as a whole; in other words, the spacing plan seeks to use the field space to the maximum. In practice the plants are grown under somewhat crowded conditions in the field. The space allotment to be chosen is conditioned very materially by the type of beet grown, the productivity of the soil, the expectations as to soil moisture, and the planting date. With productive soils likely to receive an adequate moisture supply, irrespective of planting dates, close spacing is successful. For late dates of planting, closer spacings are usually preferable, irrespective of soil conditions. In general, high-sugar types (usually small-foliaged) may be spaced closer than the tonnage-producing types, which commonly have larger tops.

A common space allotment per plant is 240 square inches, which may be secured in 20-inch rows by 12-inch spacing in the row; in 24-inch rows by 10-inch spacings; and in 18-inch rows by approximately 13-inch spacings.

There is a great diversity of opinion among growers as to the proper space to allow per plant in order to obtain the best results from the crop, individual preferences ranging from 8-inch thinning to 16-inch thinning, with rows of any of the customary intervals.

Experimental work carried on in the humid area does not indicate any optimum spacing for sugar beets. Some tests with various spacings ranging from an average of 4 inches to spacings of 20 inches have given almost identical results, while other tests have given significantly higher yields for the closer spacings.

Of relatively more importance than the determination of the ideal spacing within the row is the matter of uniformity of distribution of plants over the field surface. Undoubtedly the plant can in its growth compensate to some extent for difference in row width and row interval. Loss in yield is more likely to come from gaps in the field which, lacking plants, are idle spaces.

Under ordinary conditions a perfect stand after thinning is very seldom obtained in a commercial sugar-beet field. Even though the thinning is done with great care, there will be spaces within the row that increase the average distance between the beets and decrease the number per acre. The results of definite experimental work have shown that there are progressive drops in tonnages as the stands become poorer. This is not so marked with deviations no greater than 20 percent from a full stand; 100 beets to 100 feet in a 20-inch row is ordinarily regarded as a full stand, since the beets that remain compensate to a large extent for the loss of stand, but, as the stand becomes more and more irregular and the spaces between the beets become greater, the increase in size of the remaining beets cannot compensate for the loss of stand. The loss of tonnage due to an imperfect stand will be noted more quickly where the beets have been widely spaced than where they have been spaced close together. Furthermore, as the beets become larger their quality becomes poorer and their value per ton much less than the value of the smaller beets produced where the stand is more nearly complete.

It is therefore recommended that the closer row widths and relatively close spacings in the row be employed and that the grower should especially stress the securing and maintenance of as nearly a complete stand as possible.

CULTIVATION

The cultivating period for the sugar-beet crop may be divided into two parts: (1) The period prior to thinning, and (2) that following. The amount of cultivation necessary in either period depends upon the type of soil, the content of organic matter, the thoroughness with which the soil has been prepared, the weeds that are present, the amount of rainfall, the distance between rows, and other factors.

Since the sugar-beet seedlings are very small and cannot break a crust, it is essential during the period of germination that any crust that forms be broken immediately. To accomplish this, the cultipacker, corrugated roller, weeder (fig. 24), rotary hoe (fig. 25), or similar implement may be used. So long as the seedlings are still below the crust, there is slight danger of destroying the stand. If the crust forms later or if it is necessary merely to stir the soil to promote drying, the treatment used must be adjusted to meet the special conditions presented. After the seedlings have emerged and the rows can be seen,

prompt cultivation is extremely desirable. Not only are many of the weeds destroyed, but the drying of the surface soil checks to a large extent the advance of seedling diseases, and thus benefits the stand.

FIGURE 24.—A weeder may be used to break crusts and stir the soil lightly before thinning.

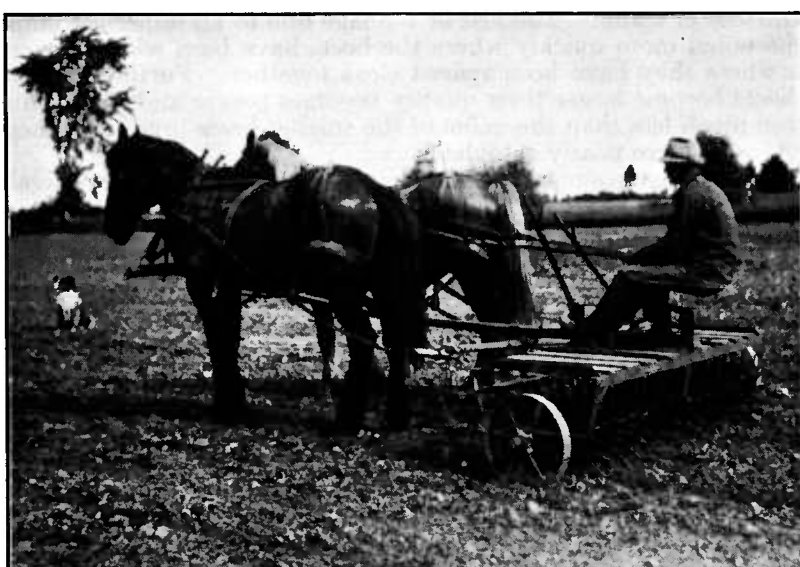

FIGURE 25.—A rotary hoe.

It is during this period that thick seeding is an advantage, for the larger number of seedlings in the row make the rows comparatively easy to follow. Irrespective of soil conditions, it is a common practice

in the humid area to roll fields. Unless a loose soil is to be compacted or a crust is to be broken, there is little justification for rolling. This practice injures the young plants and promotes conditions favorable to damping-off, so that, in general, rolling of the soil is undesirable.

The number of cultivations given following thinning is determined by the rainfall and the number of weeds that start. Fewer cultivations will be necessary on weed-free than on foul soil. These cultivations keep the soil between the rows in good condition and destroy the weeds. The cultivation may very well be terminated when the foliage covers the ground. As the ground will be covered more quickly when the rows are close together and the beets spaced fairly close together in the row, the crop can be laid by sooner than if the rows are farther apart or the beets spaced more widely. Types of cultivators have been developed that are fitted to the needs of the sugar-beet crop and will cultivate large acreages in a very short time (fig. 17).

Ordinarily two hoeings follow thinning. Usually the contract labor employed for the thinning operation does this work. The chief purpose of the hoeing should be to remove weeds, especially grasses, that have started in the row since thinning and have not been reached by the cultivator. By a proper timing of cultivations and hoeings the field should be kept free from weeds until the growth of the beets is adequate to eliminate the weed problem.

HARVESTING

In order that the crop may make all the tonnage possible and store as much sucrose in the roots as conditions will permit, the harvest is deferred as long as it is safe to do so without danger of having the crop or part of the crop frozen in the ground. However, it is practically impossible to have all the crop harvested at a time that will permit every acre to make its highest tonnage and reach highest quality, on account of labor conditions and other factors.

Ordinarily samples are taken from the commercial fields at intervals from the first of September on, to determine the quality and progress of the crop. When the harvest season approaches, harvesting orders are given, and the grower is required to harvest and deliver his tonnage at the time specified. This is necessary, as the supply of beets must be such that the operation of the factory may be continuous. If too many beets are delivered while the weather is still comparatively warm, there is great danger from loss by deterioration of the roots in the piles or bins. The fresher the beets are when sliced, the less the loss.

Although machine methods may, in the future, modify the present harvesting methods and displace the customary team or tractor and hand operations, the most of the crop is still harvested by the same methods that have been used for years.

In harvesting, the grower lifts the beets with a specially designed beet lifter (fig. 26) that loosens the beet roots and lifts them slightly, breaking off the taproot fairly deep in the ground. After lifting, the beets are sometimes pulled from the ground by hand, knocked together to remove adhering soil, and then thrown into piles, so that the topping can be done from the pile. This is advantageous, as it leaves the tops also in piles which can easily be gathered up in loads. At other times the topper, using a knife with a hook on the end, pulls and tops

FIGURE 26.—A two-row, tractor-drawn lifter. The sugar beets are loosened and lifted slightly.

FIGURE 27.—Sugar beets being topped from the row and thrown into piles.

the beets at one operation (fig. 27). When beets are topped in this way, the tops should be gathered into piles before drying takes place. If, after being lifted, the beets are thrown into windrows of four, six, eight, or even more rows to a windrow and then topped out of the windrows, the tops are much more easily gathered for later use and are much more free from soil than if the beets are pulled and topped at one operation and the tops left scattered in the field.

In topping, the crowns of small or medium-sized beets are removed by cutting directly through the beet at the lowest leaf scar. This is essential, for the crown is low in sucrose and high in minerals. If the beets were not properly topped, recovery of sugar from the roots

Figure 28.—Loading sugar beets for delivery.

would be very seriously interfered with. With large beets (usually those whose diameter at the largest part exceeds 4 inches), it is commonly permitted to remove the crown by two or more slanting cuts, leaving the top of the root pointed. A cut straight through a large beet root at the lowest leaf scar would waste root material and the sugar that it contains.

When the beets are topped, they are thrown into piles, from which they are loaded into wagons or trucks (fig. 28) for delivery at the loading station or factory. In case it is impossible to deliver the beets within a very few hours after topping, the piles should be covered with leaves to prevent the loss of weight due to loss of moisture. The longer the beets are to remain in the piles in the field, the more carefully they should be covered. The amount of weight lost by drying in the field is not always realized by the growers. Under ordinary harvest conditions, the shrinkage in uncovered piles may be more than 1 percent a day. This shrinkage is measurably reduced by proper covering with beet tops. To some extent, covering the piles protects the beets from freezing, and this is an advantage, since frozen beets are apt to spoil quickly in the bins.

SUGAR-BEET DISEASES[9]

CERCOSPORA LEAF SPOT

The most important leaf disease of the sugar beet in the humid area is leaf spot, caused by the fungus *Cercospora beticola*. This disease, as its name implies, is characterized by the production of small circular spots, approximately one-eighth inch in diameter, on the leaf blades. The petioles are also attacked, small elliptical lesions being produced. Under conditions of severe attack, the spots on leaf blade or petiole coalesce, and, as a result of the combined effect of the spotting and leaf-vein injury, severely affected leaves turn brown and die (fig. 29). The attack may be so severe that the entire field takes on a scorched appearance, commonly referred to as blight. The disease starts on the older leaves and advances to the younger leaves as they develop. Under conditions favorable to the disease, the field may show in succession blighting, apparent recovery, followed by another wave of blighting, and so on, until finally under cool fall conditions the disease is checked.

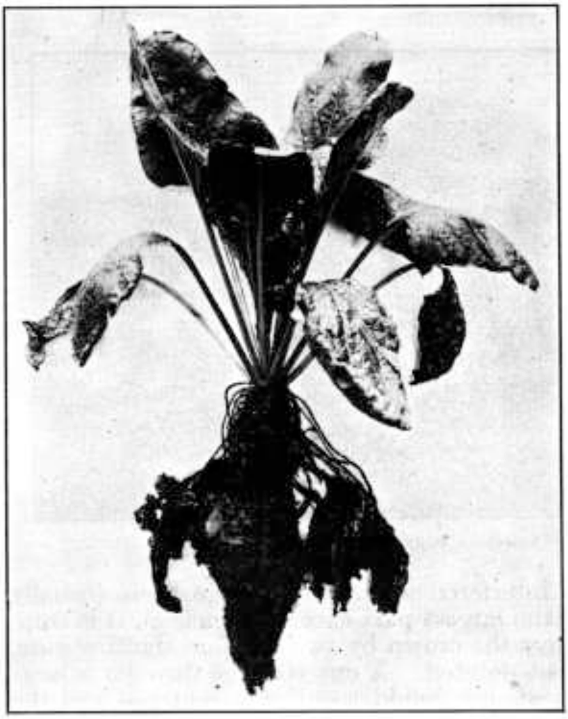

FIGURE 29.—Effect of sugar beet leaf spot caused by the fungus *Cercospora beticola*.

To understand the nature of leaf spot and its effects, it is necessary to recognize that the disease is the result of the attack of a fungus, which obtains its food from beet foliage. The fungus may occur on beet seed and in this way be introduced into the field each year. Probably only a plant here and there in the field becomes diseased from this source of infection. Under favorable conditions, as will be explained, this is enough to bring about an epidemic condition. A more abundant source of infection is furnished by the trash and debris from a previous beet crop. Although severe blighting may not have occurred and the farmer may not have seen leaf spot in the beet field, the disease is probably present every year in every field. It has been shown that the fungus can live over on dried tops at least 3 years. Where beets follow beets too closely in the rotation, the young plants are exposed not only to the infection of seed origin but to the more

[9] Contributed by G. H. Coons, Dewey Stewart, and J. E. Kotila.

extensive infection which comes from the diseased leaves of a previous beet crop.

The climatic conditions of a particular season determine whether leaf spot will produce severe effects or not. The fungus requires high temperatures for its rapid propagation, being definitely checked by cool spring or summer conditions. Rainy periods, spaced a week or two apart, and prevailingly warm conditions in the first half of the growing season allow the fungus to go through several successive cycles of increase, and thus the disease arising from the primary infections becomes so distributed in the field that every plant is affected. With favorable midsummer conditions for growth and spread of the fungus, severe foliage injury results.

Where wholesale blighting of leaves occurs early, both tonnage and sucrose percentage are lowered. The plant produces successive whorls of leaves only to have them destroyed. The late attacks, which come after the root growth is largely made, show their effects in the sharply decreased sucrose percentages. Early leaf spot epidemics may reduce the acre yields of roots 2 tons or more and depress sucrose percentage by 2 units or more. For the average crop the combination of reduced root yield and low quality may result in a loss of 25 percent or more. Effects of late attacks may be seen chiefly in the lowered quality of roots.

CONTROL OF LEAF SPOT

Seed treatment has not been effective in control of cercospora leaf spot, since the seed is only one of the primary sources of introduction of the disease in the fields. Application of bordeaux mixture or the dusting with copper fungicides is effective for leaf spot control. At least three or four applications, begun early in the season, are required. In areas where the disease does damage nearly every year, such protective measures would be warranted and would show definite gains. In many districts of the humid area, however, the disease occurs only periodically. In Michigan, for example, the years of widespread occurrence were 1914, 1915, 1921, 1924, 1935, and 1937, with slight or localized damage in other years. These blight years are unpredictable in advance. Effective control by dusting or spraying cannot be accomplished by waiting to see if the disease is going to develop to serious proportions, because by the time the disease effects are plainly evident the younger leaves have already become infected, and the protection which the fungicidal sprays or dusts give comes too late. Hence, where the outbreaks are not regular occurrences, the cost of machinery and of sprays or dusts, together with the loss which comes from foliage injury in the course of applying the fungicides, operate to make the use of these direct-control measures uneconomical, even though in the blight years they would produce very definite benefit.

An essential for control of sugar-beet leaf spot is close adherence to a rotation system in which sugar beets do not follow sugar beets, and, in general, at least 3 years intervene between sugar-beet crops. With such a rotation system, the heavy exposure to infection which arises from the fungus that persists on debris from a preceding crop is avoided. Irrespective of variety to be planted, this sanitation measure is of value.

LEAF SPOT RESISTANT VARIETIES

As a result of breeding work by the United States Department of Agriculture, improved varieties of sugar beets, which under conditions of leaf spot exposure are far less seriously injured than any of the European brands, are now available. In 1937, for example, under conditions of severe leaf spot in Michigan, the recently introduced variety U. S. 217 made an excellent showing. Previous tests had shown that this variety, under conditions where leaf spot was not a factor, closely approximated the best European brands in performance and was superior to the average of imported brands now available. As this variety and others shortly to be introduced are multiplied to the amounts required for commercial plantings, they will be substituted for the nonresistant sorts.

These varieties are, however, not immune to leaf spot; hence some spotting of the leaves occurs, and older leaves die earlier than normal. They do not, however, show the excessive burning and foliage destruction of ordinary European brands. Since these varieties are so rapidly approaching the point where under all conditions they compare favorably with the European brands and under leaf spot conditions produce more nearly normal tonnages and sucrose percentages, it is not too much to expect that the disastrous results of blight years will not be experienced as the use of the varieties improved in resistance becomes general.

SEEDLING DISEASES

Stands of sugar beets in the humid area are often seriously reduced and made irregular because of damping-off of seedlings either as they emerge from the seed balls or in early stages of growth. The death of the young plants is caused by the attack of parasitic organisms. Several species of fungi are known to be capable of producing these effects. One is commonly seed-borne (*Phoma betae*), and others (*Pythium* spp., *Rhizoctonia* spp., and *Aphanomyces* spp.) are more or less prevalent in all agricultural soils. The appearance of injured plants is very similar, irrespective of the species causing the disease, and is fairly well described by the term "black root," which growers commonly give to this condition (fig. 30).

Examination of clumps of beet seedlings shortly after emergence from the soil usually will reveal occasional plants with brown or black, sunken, elliptical lesions or with completely girdled hypocotyls (the portion of the stem between the seed leaves and the root). Severely injured plants topple over, the affected tissues turning black and drying to a thread. Less severely invaded plants may continue growth and, in some cases, apparently recover. Some of the organisms that cause damping-off, or black root, may be concerned with root and crown rots, which develop later in the season. From the relatively few affected plants, the disease spreads to neighboring plants if conditions favor the disease, so that blank spaces of 2 or more feet may occur in the row. Such gappy initial stands of seedlings make it impossible to secure uniformly spaced plants after thinning.

In general the prevalence of seedling diseases is greatest if the soil is wet and if conditions are such that growth of the young beet plant is retarded. The disease is worse in poorly drained fields than in fields that are well drained. Aeration of the soil to promote drying serves to check the spread of the disease along the row.

In the control of black root attention must be given to a number of factors which together, in many seasons, operate to make seedling diseases the most important of any with which the sugar beet has to contend.

CONTROL

ROTATION

The sugar beet should be grown in the proper sequence with other crops of the rotation. The seriousness of damping-off is directly connected with the prevalence in the soil of certain classes of soil organisms. Certain crops and certain practices may favor, for example, the organisms which cause damping-off or black root, whereas other crops and other conditions repress these pathogens by favoring other types of soil organisms. Experimental evidence and abundant

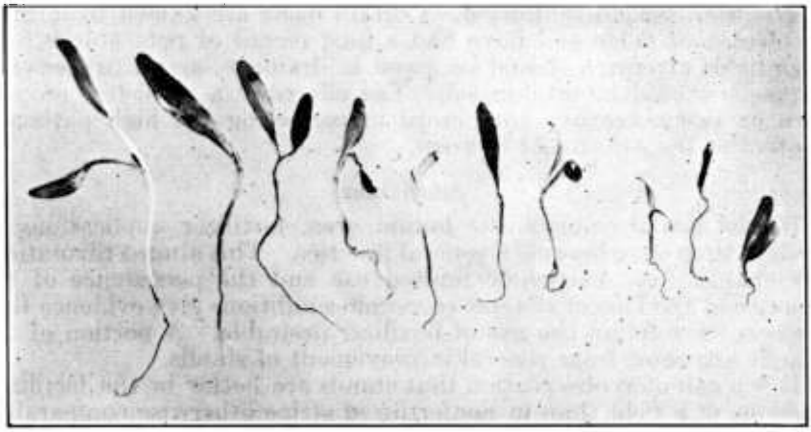

FIGURE 30.—Damping-off of sugar-beet seedlings (black root). This disease is the cause of poor stands.

field experience show that sugar-beet stands in general are better when sugar beets immediately follow corn than when they follow alfalfa, sweetclover, red clover, or crimson clover. Corn has definitely been shown to exercise a sanitary effect on the soil, apparently bringing about great reduction of the pathogens that attack beet seedlings. On the other hand, the legumes named definitely increase the pathogens capable of attacking beets. Other crops, such as small grains, potatoes, beans, and soybeans, where an adequate period for decay of stubble is allowed, while not so outstanding as corn, either are somewhat beneficial or, at least, do not favor the pathogens.

Certain weeds growing in thick stands have been found to increase the damping-off of sugar beets; clean-culture crops preceding beets may in part give beneficial results because of weed control. Conversely, the occurrence of severe damping-off, when beets follow poor or neglected stands of corn or other crops that ordinarily would be satisfactory as preceding crops, may be brought about by weediness of these stands. Cases of poor stand in sugar beets following corn have been found to be attributable to sweetclover or alfalfa, which, persisting as a weed, nullified the beneficial effects of corn.

It will be noted in the examples of successful rotations in use in the humid area that sugar beets frequently follow corn and do not immediately follow the clovers or other green-manure legumes. In certain districts the practice of having beets follow corn is almost general. Although the legumes named should not immediately precede the beet crop, this does not gainsay in any way their value in the rotation. These crops have definite and well-recognized value, but they should be used in their proper place in the rotation.

ADEQUATE DRAINAGE

Since the damping-off diseases are favored by high moisture content of the soil, the field chosen for sugar beets should have good natural drainage or should be adequately tiled. Attention needs also to be given to the main ditches, which carry off the field drainage. Adequate drainage benefits other crops as well as the sugar beet and is essential to field sanitation. Certain fields are known to farmers as black-root fields and have had a long record of poor stands. In such fields attention should be given to drainage, and a proper crop sequence should be established. The effects of a weed-free crop of corn or two successive corn crops in correcting the high pathogen content of the soil should be tried.

FERTILIZERS

In the last decade in the humid area, fertilizer applications at seeding time have become a general practice. This almost revolutionary change from extremely limited use and the persistence of the practice in the face of adverse economic conditions give evidence that growers have found the use of fertilizer desirable. A portion of the benefit has come from general improvement of stands.

It is a common observation that stands are better in the fertilized portions of a field than in nonfertilized strips otherwise comparable. Many soils are deficient in fertility, and, in certain soil types, phosphate may be less available in the spring than later in the season when microbic and other factors have freed it from the soil reserves. The furnishing of readily available plant food as the young plant is getting established and at the time when its food-gathering root system is small may be the significant factor which favors the plant and prevents invasion by soil or seed-borne pathogens. The nature of this favorable action of fertilizers is not known, since, in general, the relations of nutrition to resistance or susceptibility have only been explored to a limited extent. There is clear evidence, however, that beet roots well-nourished with respect to phosphate are definitely more resistant to invasion by *Phoma betae*, a common cause of root rot and also of damping-off, than poorly nourished roots; such may also hold true with respect to other organisms attacking the sugar beet. It is possible also that fertilizer may produce its beneficial effects upon a stand simply by enabling the seedlings to pass more quickly to a more resistant stage, since it seems that the beet is most subject to damping-off at sprouting time and in the emergence period.

SEED TREATMENTS

Experiments over many years have shown that the dusting of sugar-beet seed with fungicidal dusts of copper compounds, mercurials, or combinations of these two chemicals often has strikingly beneficial

effects. There are conditions for growth in which stands are not affected by damping-off, and under such conditions the treatmentshows no advantage, but may, in fact, cause slight retardation of early growth. Seed treatment has not been uniformly successful in controlling damping-off. With certain soils, it has failed to show advantage, as, for example, in the Brookston clay soils of Ohio and in heavy soils in Michigan. In lighter soils and in tests in Minnesota and Iowa beneficial effects have been attained.

Seed treatment with copper compounds, and especially with mercurials whose value as a seed treatment has been shown with other crops, may be recommended in many areas as valuable in reducing to some extent, at least, the full effects of damping-off. Effectiveness of treatment will be augmented if full attention is given to the other factors mentioned that condition the damping-off exposure.

A fungicidal dust to be effective with sugar beets must greatly reduce the infection that comes from the seed and must, in addition, disinfect a small zone of soil around the germinating plant, in order to protect it against the serious injury that may come from soil-borne damping-off organisms. Since the period in which the young plant is susceptible may extend over several weeks, the fungicide must persist in the soil in order to give reasonable protection.

Dust treatments may be applied to beet seed by the same methods as those employed in treating grains with these chemicals. To secure a fairly complete coverage, approximately 3 to 4 ounces of dust per 15 pounds of seed is required. The seed should be dusted shortly before use and in no greater amount than is to be planted, since under certain conditions germination may be adversely affected.

PROMPT CULTIVATION

The value of prompt cultivation, previously discussed (p. 33), comes in part from its very significant contribution to damping-off control. In general the organisms attacking the young beet plant are favored by high-moisture conditions, especially those that allow a film of water to remain on or near the surface. Under such conditions, the organisms spread rapidly from plant to plant and involve all the beets in the clump. Cultivating as soon as the rows can be followed aerates and dries the soil checking the advance of damping-off. Many stands apparently hopeless have been saved by prompt and thorough soil stirring, either by the cultivator or some other tool that breaks the crust and loosens the soil near the small seedlings.

In any season, sugar beets should be cultivated as soon as the rows can be followed through the field.

SELECTIVE THINNING

The general measures, previously discussed (p. 41), will do much to reduce the seedling-disease problem. If the season is favorable and seedbed conditions have promoted prompt, vigorous plant growth, losses in the initial stand may be at a minimum. With such a situation, early thinning, which avoids the bad effects from overcrowding among the young plants, is usually desirable. However, when damping-off is serious, as manifested by the presence of many seedlings in a clump showing blackened, diseased shanks, it is very important that thinning be delayed until by subsequent growth the healthy seedlings can be distinguished because of their vigorous,

sturdy growth, in contrast to the stunted growth of diseased plants. Selection of the sturdy, rapidly growing plants will avoid the severe losses that occur in a stand of thinned plants when the affected plants are left by the thinners. Close supervision of the laborers doing the thinning is very important if a good stand of thinned beets is to be obtained.

ROOT ROT

Although the sugar beet is subject to many types of root rot, in the humid area that caused by *Rhizoctonia* spp. has occasioned the most serious damage. This rot commonly shows up fairly late in summer and usually takes the form of a crown rot. It is characteristic of crown rot that clefts appear in the root at or near the crown. This disease is first noted in the field by the presence of occasional plants whose older leaves are dying.

This stage is followed by wilting and death of the younger leaves. Roots of affected plants are found to be partially or completely decayed, the invaded tissue being blackish brown. The rather coarse brown threads of the rhizoctonia fungus can be seen on the roots, often filling the cleft as a weblike brown skein.

There is evidence to indicate that rhizoctonia rot may trace back to partially outgrown seedling infection. Under conditions in which the growth of the beet has been halted, the fungus invades the tissue and forms a canker. When rapid growth sets in, following a rainy period, the growth of normal tissue sets up such tension around the cankered area that the root cracks. The invading organism continues to advance in the tissue until the entire root is decayed.

A number of successive plants along a row may show rhizoctonia root rot. It seems that as the lower leaves die as a result of cankers around the bases of the petioles, the fungus invades the leaf tissue and infects leaves on neighboring plants in the row whose lower leaves touch the affected leaves.

It is obvious that any control of rhizoctonia root rot must take the form of preventive measures. If, as seems likely, the disease may trace back to attack in the seedling stage, the measures outlined to secure healthy seedlings have definite applicability to root rot prevention in the older plants. The same relations to preceding crops as noted for prevalence of seedling diseases have been found to apply to rhizoctonia root rot prevalence. Observations in many areas have shown rotting of mature beets to be less where beets follow corn in the rotation than where beets follow alfalfa, sweetclover, or the clovers. Obviously, the points made respecting drainage, fertilization, and cultivation will have general beneficial effects in preventing root rot.

INSECT ENEMIES [10]

Although there are, in the humid area, a number of insects or their larvae that feed upon the foliage or roots of the sugar beet, there are none that cause widespread damage. However, there are some that cause local damage, entire fields being ruined while adjacent fields show little or no injury. The most important of these are cutworms (fig. 31), white grubs, wireworms, flea beetles, grasshoppers, and occasionally webworms.

[10] Prepared by W. H. White, Division of Truck-Crop Insects, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Cutworms are the young or immature forms of medium-sized, dark-colored moths or millers and are usually more destructive in fields that have not been cultivated the previous season, as many of the species of cutworm moths prefer to deposit their eggs in areas covered with vegetation. The principal damage done by cutworms to the beet crop usually occurs early in the season, when the plants are small. Cutworms may overwinter in the soil in the half-grown or nearly mature stage, and as soon as the weather begins to warm in the spring they become active and feed upon any available vegetation. They feed at night, cutting off the rows of seedlings near the surface of the soil. During the day they hide beneath clods of earth or in the soil a little below the surface.

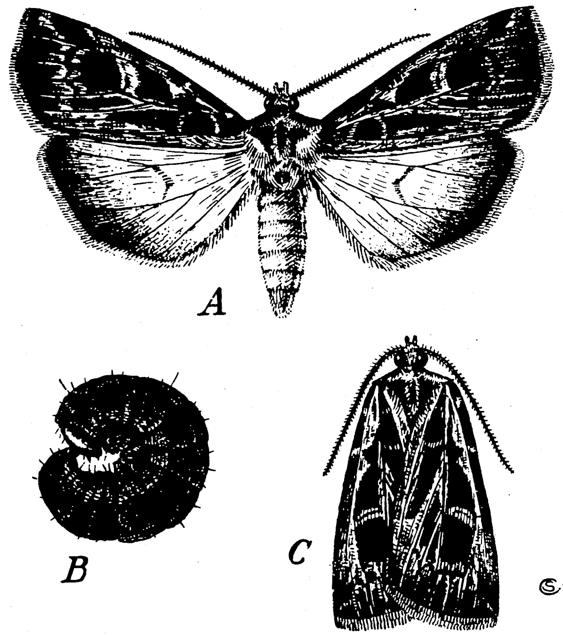

FIGURE 31.—Cutworm: *A*, Moth, wings expanded; *B*, larva or cutworm; *C*, moth, wings natural position when at rest.

Cutworms can be readily controlled by the use of poisoned bran mash or bait spread along the rows throughout the infested part of the field late in the evening.

White grubs are the larvae or young of the common May beetles. Their normal habitat is in grasslands, but they will feed upon the roots of other plants. There are many different kinds of white grubs, the majority of which require 3 years for full development. Therefore, any crop following a grass or clover sod the first, second, or third year may suffer damage.

These pests are difficult to control, but much of the damage to the crop can be prevented by planting the beets in land that has been under cultivation for at least 2 years. Fall plowing should be done before the grubs go deep into the ground to pass the winter. This should be prior to October 10, in many sections.

Wireworms, the larvae of the click beetles, sometimes are destructive in certain lands. The kinds of wireworms that are found in the humid beet-growing area favor grasslands, and one species inhabits lands that are poorly drained. Wireworms require from 3 to 4 years to reach their full development; therefore, the beet crop following sod may suffer damage over a period of years.

These pests are also difficult to control, but some relief may be obtained by following the methods suggested for white grubs; that is, fall plowing and avoiding planting beets on fresh sod or grasslands.

Low, wet, or sour lands should be drained, if possible, as the wireworms that inhabit such types of soil do not thrive in well-drained areas. Clover and buckwheat are not particularly susceptible to damage by wireworms, and these crops may be grown in areas that are heavily infested before the beet crop is planted.

Several kinds of flea beetles may attack the beets in the seedling stage by feeding upon the leaves. Under hot, dry conditions unfavorable to the proper growth of the crop, these insects may destroy

FIGURE 32.—Grasshopper injury.

an entire stand in a comparatively short time. Lime applied direct to the foliage of the plants in liberal quantities will act as a repellent to these pests, and satisfactory results have been secured from using hydrated lime at the rate of from 50 to 150 pounds per acre, spreading the lime with the ordinary beet drill with the tubes pulled out of the shoes and fastened so that the lime is discharged directly over the beet rows.

Grasshoppers occasionally do considerable damage (fig. 32) to the young crop, but they can be satisfactorily controlled by the use of poisoned-bran bait. The mash or bait should be scattered over the fields wherever the crop is threatened by a grasshopper attack.

BYPRODUCTS [11]

There are several byproducts of the sugar beet and the beet-sugar industry that are distinctly of agricultural significance. The most important of these is the forage supplied by the leaves and crowns

[11] For further information on beet-top silage and other byproducts of the sugar beet, see Farmers' Bulletin 1718, Important Sugar-Beet Byproducts and Their Utilization. Lime cake or filter press cake, as waste lime from the factory is called, is discussed on pp. 18 and 19.

that are left from harvesting. Other byproducts, such as beet pulp, molasses, and lime cake or waste lime, also have considerable agricultural value.

The weight of tops and crowns produced in a field of sugar beets varies according to the yield of roots obtained and the amount of leaf spot prevalent. The weight of fresh tops and crowns will often equal the weight of roots, but, under certain conditions, may be as little as one-fourth their weight. Much of the weight is lost in drying, but the dried tops are still palatable feed for cattle. From the ordinary beet crop, therefore, 5 to 8 tons per acre of material suitable for forage can be expected as an additional return from the beet crop.

While the beet tops and crowns have a very definite and considerable value as a source of organic matter for the soil and as a fertilizer for the succeeding crop, greater value can be obtained from them if they are utilized as feed for livestock and the manure produced spread upon the fields. The tops may be utilized by pasturing cattle and sheep upon them in the field, or they may be ensiled. If they are pastured, a considerable portion of the feeding value is lost by the tops being trampled into the ground, but this method of utilization eliminates the cost of handling. Since the crown contains salts that are very laxative, it is advisable, when the tops are to be pastured, to limit the period of time each day that the stock is allowed to feed upon them.

It is much easier to gather the tops for siloing when the beets have been windrowed before being topped. Whether the beets have been topped from piles, windrows, or their place in the row, the tops should be gathered while green to avoid loss, which occurs when dried tops are handled. Tops from windrowed beets are freer from dirt than are tops from beets that have not been windrowed, and this is an important consideration as to the harvest method to be employed. It is advisable to mix straw or corn stover with the tops to absorb the excess moisture when they are put in the silo. This mixture makes a highly desirable silage. If the mixture is to be placed in an ordinary silo (fig. 33) the mixing should be done as the material is put through the cutter. If the tops are siloed in a rick, they are not run through the cutter, but the straw and tops are stacked in alternate layers, each about a foot thick, the whole pile being covered with a layer of straw upon which some earth is placed.

The feeding value of beet-top silage, while probably varying considerably, is indicated by comparison with corn silage, as shown in table 4.

TABLE 4.—*Comparative analyses of beet tops and corn-stover silage* [1]

Items of comparison [2]	Total dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio	Average total composition				
					Protein	Fat	Fiber	Nitrogen-free extract	Mineral matter
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sugar-beet tops	27.0	1.8	11.8	1:5.6	3.5	0.7	3.0	11.3	[3] 8.5
Corn, dent (ears removed)	22.6	.8	13.6	1:16.0	1.5	.6	7.7	11.3	1.5

[1] From Morrison's Feeds and Feeding, twentieth edition, 1936.
[2] 8 analyses averaged for each item of comparison.
[3] Dirt gathered with the tops increased the mineral matter found.

In processing the sugar beets, the roots are sliced into cossettes and the sugar extracted. The extracted cossettes are known as beet pulp. Fresh or wet pulp is bulky, but in many districts it is hauled from the factory and fed. In the western part of the United States, large feeding operations take advantage of this important cattle feed. In the humid area practically all the pulp produced is dried before being sold.

FIGURE 33.—Making silage from beet tops and corn stover.

Often the dried pulp is mixed with molasses and sold as molasses pulp. The dried-beet pulp and molasses pulp are important constituents of stock feed.

The residue from the sugar-refining processes, consisting of uncrystallizable sugar and various mineral constituents, is called beet molasses. It has a high feeding value and, where available, can be utilized for feeding cattle and other livestock. Some is used in making molasses silage. The composition and feeding value of the dry pulp and the beet molasses, in comparison with standard feeds, are shown in table 5.

TABLE 5.—*Comparison of the digestible nutrients in the concentrates barley, corn, dried-beet pulp, and beet molasses and the roughages alfalfa hay and timothy hay* [1]

Feed	Water	Ash	Crude protein	Carbohydrates: Crude fiber	Carbohydrates: Nitrogen-free extract	Fat or ether extract	Digestible protein	Digestible carbohydrate equivalent
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Dried-beet pulp	8.4	3.5	9.3	18.7	59.3	0.8	4.9	66.0
Beet molasses	20.8	10.6	9.1	----------	59.5	----------	----------	----------
Corn	12.9	1.3	9.3	1.9	70.3	4.3	----------	----------
Barley	9.6	2.9	12.8	5.5	66.9	2.3	10.4	63.8
Alfalfa hay	8.3	8.9	16.0	27.1	37.1	2.6	11.5	42.0
Timothy hay	12.5	5.4	6.8	28.3	44.3	2.7	3.3	44.7

[1] From Farmers' Bulletin 1718. Compiled by the Cereal Section, Food and Drug Administration, and the Animal Husbandry Division, Bureau of Animal Industry, U, S. Department of Agriculture. The carbohydrate equivalent is the sum of the digestible crude fiber and nitrogen-free extract plus 2.25 times the digestible fat.

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U. S. GOVERNMENT PRINTING OFFICE: 1939

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